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(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

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JUNE, 1953—VOL. 25, No. 6

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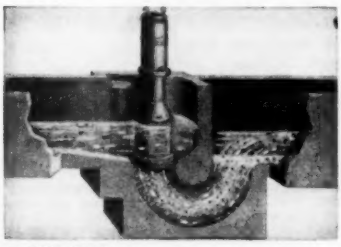

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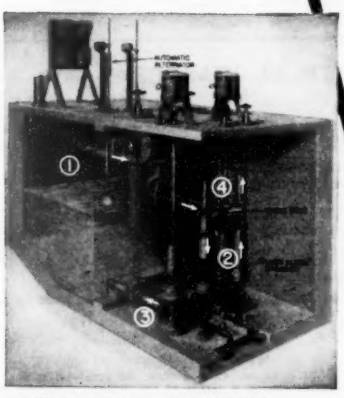

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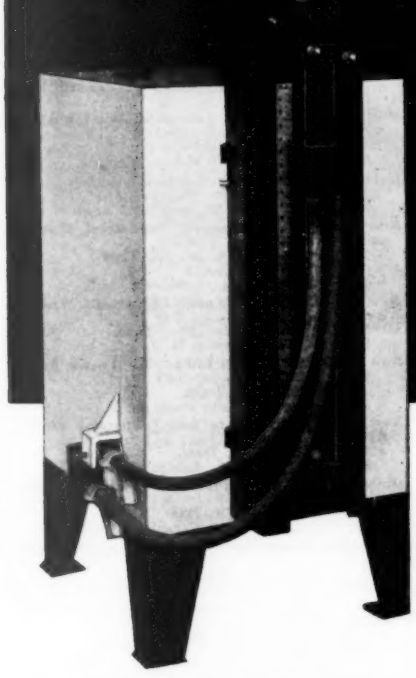

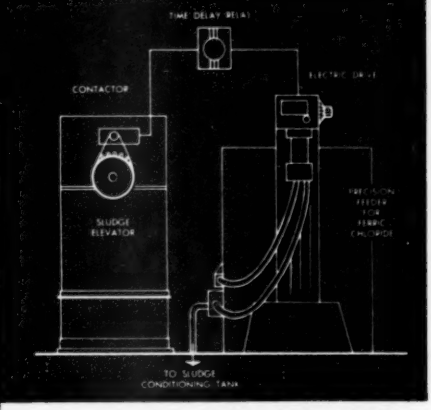

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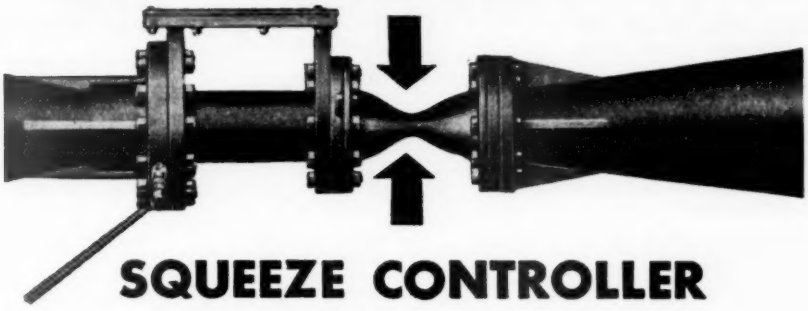

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MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Ohio Sewage and Industrial Wastes Treatment Conference	Mayflower Hotel, Akron, Ohio	June 17–19, 1953
Pennsylvania Sewage and Industrial Wastes Assn.	Pa. State College, State College, Pa.	Aug. 26–28, 1953
West Virginia Sewage and Industrial Wastes Association	Hotel Morgan, Morgantown, W. Va.	Sept. 2–3, 1953
Iowa Sewage Works Assn.	Iowa State College, Ames, Iowa	Sept. 2–4, 1953
Rocky Mountain Sewage Works Association	Hotel La Fonda, Santa Fe, N. M.	Sept. 21, 1953
Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.	Owensboro Hotel, Owensboro, Ky.	Sept. 21–23, 1953
Michigan Sewage and Industrial Wastes Association	Michigan State College, Kellogg Center, East Lansing, Mich.	Sept. 21–23, 1953
Missouri Water and Sewerage Conference	Elms Hotel, Excelsior Springs, Mo.	Sept. 27–29, 1953

TWENTY-SIXTH ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations
in conjunction with
Florida Sewage and Industrial Wastes Association
Municipal (Bayfront Park) Auditorium, Miami, Florida
October 13–16, 1953

Address hotel reservation requests to: FSIWA Convention Housing Bureau, 320 N.E. Fifth Street, Miami, Florida

Canadian Institute on Sewage and Sanitation	General Brock Hotel, Niagara Falls, Ont., Can.	Oct. 26–28, 1953
New England Sewage and Industrial Wastes Association	Wannamoisett Country Club, 96 Hoyt Avenue, East Providence, R. I.	Nov. 5, 1953
Pacific Northwest Sewage and Industrial Wastes Association	Hotel Chinook, Yakima, Washington,	Nov. 5–7, 1953
North Carolina Sewage and Industrial Waste Association	Sheraton Hotel, High Point, N. C.	Nov. 9–11, 1953
Nebraska Sewage and Industrial Wastes Association	Hotel Capital, Lincoln, Nebr.	Nov. 12–13, 1953
Oklahoma Water, Sewage and Industrial Waste Conference	Okla. A & M College, Stillwater, Okla.	Nov. 16–20, 1953

Briefs from the YEOMANS GUARD

90% B.O.D. Removal in "Aero-Filter" Plant at Plant City, Fla.

How's this for a letter?

"The Florida State Board of Health joins the City of Plant City in its pride in having such an excellent sewage treatment plant." The letter to T. J. McCall, City Manager, continues "and certainly Plant City has set an example which would be very profitable for other cities to follow."

In a later letter the State Board of Health added, ". . . we now have almost a year's operating data on this plant . . . and apparently it is achieving a B.O.D. removal in excess of 90 per cent."

This all-Yeomans waste treatment plant, built around an "Aero-Filter" and four dual Streamline Sludge Collectors, was designed by Alan B. Pimm, Consulting Engineer of Tampa, Fla., to meet the needs of the present population of approximately 10,000 with provision for possible future population growth to 15,000.

The happy sequel to this success story is the fact that numerous other communities *are* following Plant City's example. They're specifying Yeomans treatment equipment and getting high efficiency at low cost.

Three More Commandments for Pump Maintenance

A centrifugal pump's function is to pump liquid—not air; and air leakage will cause a pump to lose suction. To prevent that leakage, a centrifugal pump has a stuffing box—a casing, rings of packing, seal caps, and a gland at the outside end.

Observing these three simple rules will pay off in pump efficience:

1. *Replace packing periodically—using recommended packing.* Forcing in a ring or two of new packing is *bad practice*—likely to displace the seal cage.

Put in each packing ring separately, and seat it firmly before adding the next. Stagger adjacent rings, so that ends do not coincide.

2. *Never tighten a gland more than necessary*—excessive pressure will wear shaft sleeves.

3. *Replace badly scored shaft sleeves immediately*—or packing will not last long.

These and other common-sense rules make Manual 2000 a "must" for your maintenance staff.

☐ Please send Manual 2000.

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No Payment Problem—simple in design, standardized, this compact unit is low priced, easy to pay for.

See Bulletin 6251, page 8.

☐ Please send Bulletin 6251.

The Yeomans Guard, published several times a year, is a compendium of news and useful information covering the pumping of materials and the treatment of wastes, both domestic and industrial. We shall be pleased to send you the current issue if you'd care to have it. Ask your local Yeomans Representative—listed in the telephone book yellow pages under "Pumps"—or write direct.

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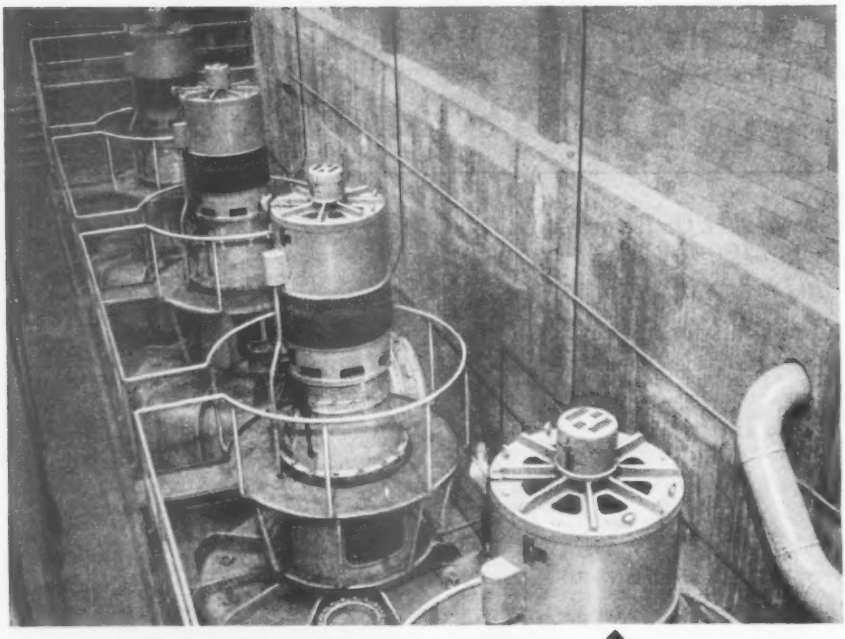
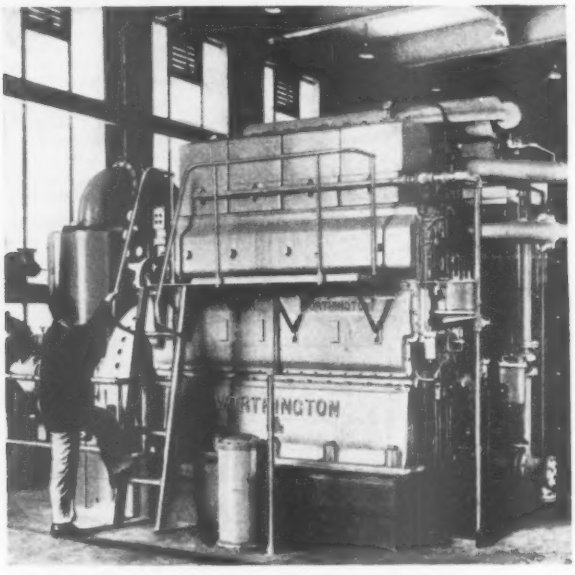
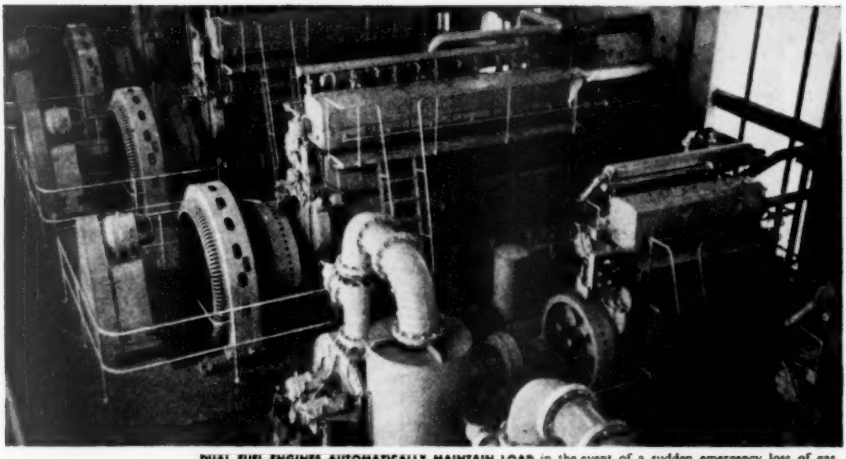


FOUR OF THESE WORTHINGTON MIXFLO PUMPS, each with a capacity of 83 million gallons per day, move sewage through various stages of its treatment at Boston's Nut Island Plant. The pumps are designed to operate at variable speeds through the use of the magnetic drive which in connection with Worthington float control will maintain a pump-well level of not more than 3 inches above or below normal—even though pumping rates vary between 35 and 300 mgd.



PRESENTLY USING SEWAGE GAS AS FUEL, these Worthington dual fuel engines are designed to operate on either gas or oil. They will maintain load in the event of a sudden emergency loss of gas supply by automatically switching to oil. Two of these 215-hp units drive the sewage aeration blowers at Boston's new sewage treatment plant at Nut Island.



DUAL FUEL ENGINES AUTOMATICALLY MAINTAIN LOAD in the event of a sudden emergency loss of gas supply. These two 820-hp dual fuel engines and one 830-hp spark ignition gas engine drive three Electric Machinery generators. Two 215-hp dual fuel engines in the foreground drive positive displacement blowers.

Worthington equipment at Nut Island Plant helps Boston reclaim Quincy Bay beaches

Mixflo pumps have maximum capacity of more than 300 mgd of sewage

The new $10,000,000 Nut Island Plant at Quincy, Mass., is now treating 95 mgd of raw sewage which was previously pumped directly into Quincy Bay.

Four large Worthington Mixflo pumps, with Electric Machinery motor and magnetic drive, each with a capacity of 83 mgd, give this modern sewage treatment plant a reserve potential to meet any future demands.

Three large Worthington dual fuel engines drive the Electric Machinery generators which power the entire plant. Two smaller Worthington dual fuel engines drive the blowers for aeration of the sewage.

In addition to its larger pumps and engines shown here, Worthington also supplies comminutors, smaller sewage pumps, sludge removal pumps, and vertical turbine pumps for the water and sewage field.

Write us for a list of Worthington installations in your area, and complete information on how Worthington equipment can solve your sewerage problem. Worthington Corporation, Public Works Division, Section W.3.1, Harrison, N. J.

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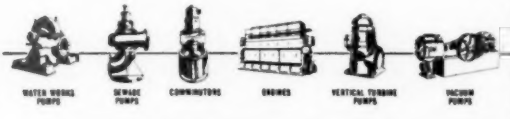

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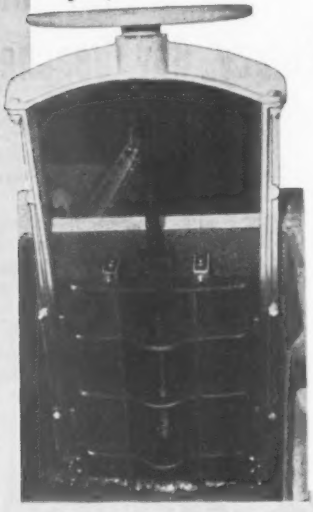

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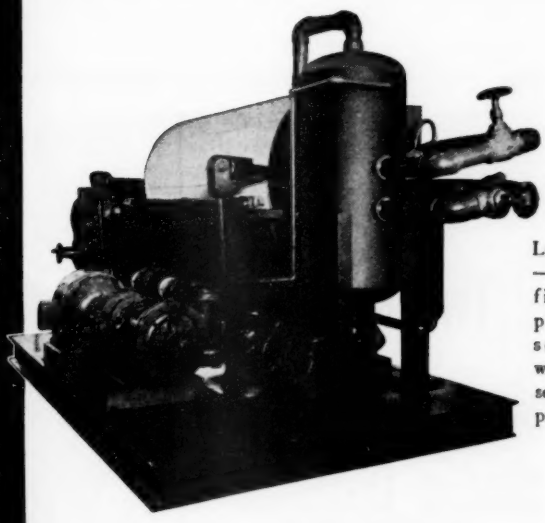
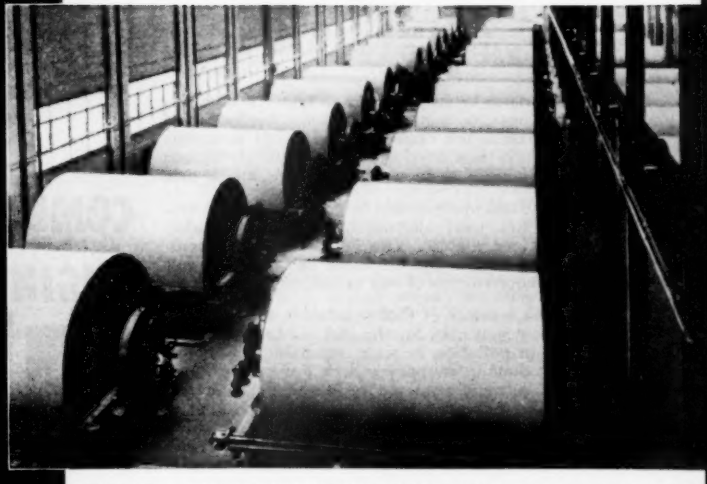
dependable process equipment built to fit your needs



Large or small—a Conkey filtration plant can serve you well. Left, a self-contained package unit.

CONKEY FILTERS FOR SLUDGE

66 Conkey Sludge Filters installed in one plant of Chicago Sanitary District. Built to exacting specifications and rigid design requirements.



PROCESS EQUIPMENT DIVISION
GENERAL AMERICAN
TRADE MARK

PROCESS EQUIPMENT DIVISION

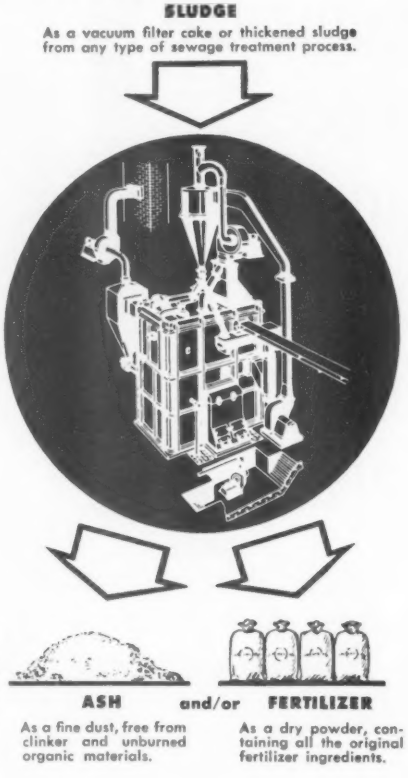
Send for latest bulletin on Filters

GENERAL AMERICAN TRANSPORTATION CORPORATION

Sales Office: 10 East 49th Street, New York 17, New York
General Offices: 135 South La Salle Street, Chicago 90, Illinois
In Canada: Canadian Locomotive Company, Ltd., Kingston, Ontario
OFFICES IN ALL PRINCIPAL CITIES

Other General American Equipment: Turbo-Mixers • Evaporators • Dewaterers • Towers • Tanks • • Dryers • Pressure Vessels

These Two Methods End Sludge Disposal Problems


SLUDGE
As a vacuum filter cake or thickened sludge from any type of sewage treatment process.
ASH
and/or
FERTILIZER
As a fine dust, free from clinker and unburned organic materials.
As a dry powder, containing all the original fertilizer ingredients.

Effective as modern processes of sewage *treatment* are, they can lose much of their value if proper sludge disposal methods are not adopted.

The C-E Raymond System of Flash Drying and Incineration offers two completely modern methods of sewage sludge disposal — both performed by compact, reliable equipment.

Flash Drying by the C-E Raymond System is a continuous process in which vacuum filtered sludge — if uncontaminated with undesirable industrial wastes — is efficiently heat dried to a marketable fertilizer or soil conditioner retaining all its original nitrogen, but eliminating the objectionable qualities of the original wet sludge. In a well designed and operated "activated plant" the revenue from the sale of fertilizer is sufficent to cover the operating costs of both the drying and vacuum filtration.

Incineration by the C-E Raymond System is an alternate, optional method. Where the production of fertilizer is not desired or the sludge is unsuitable, it is flash dried and then completely burned *in suspension* to an easily disposable, sterile ash.

The two methods can be combined in one system and used alternately as current market situations dictate. The entire design is completely flexible and can easily be tailored to suit the requirements of any community.

The services of C-E specialists are available to help you plan for the end of atmospheric or stream pollution in your community, as it has been done in so many others. For prompt, specific recommendations on the most practical answer to your sludge disposal problems, get in touch with one of the Combustion offices listed at the right. B634A

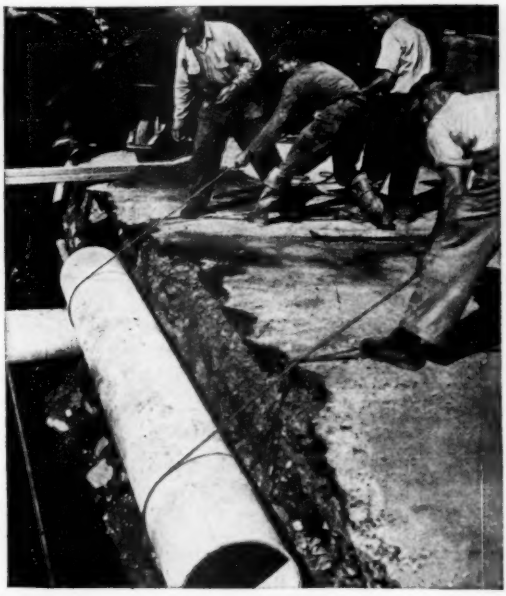
Industrial Sludges, Too *are effectively and economically disposed of in C-E Raymond Flash Drying and Incineration Equipment. Write for details.*

COMBUSTION ENGINEERING, INC.
FLASH DRYER DIVISION

1315 North Branch Street
Chicago 22, Illinois

Western Office: 510 W. Sixth
Los Angeles 14, Calif.
Eastern Office: 200 Madison Ave.
New York 16, N. Y.

You can cut installation costs ... lay pipe faster... speed completion of entire job...



—Because of this RING-TITE JOINT used with Transite Sewer Pipe

Long 13-foot lengths of Transite* Pipe are rapidly assembled with the Ring-Tite Coupling. With it, dollars-and-cents savings will be realized every step of the way during construction of the line.

The 13-foot lengths reduce the number of joints and permit the pipe to be brought quickly and accurately to grade. Still more time is saved since each Ring-Tite joint can be checked as fast as it is assembled to reduce delays in backfilling, and speed completion of the job.

LIGHT IN WEIGHT

Other money-saving advantages of Transite Sewer Pipe are found in its light weight and easy handling which reduce trucking costs and pay off in simplified operation. And, too, the Ring-Tite joint eliminates the necessity for hot compounds and the time-consuming procedures that go with their use.

May we send you more facts about this asbestos-cement pipe and its Ring-Tite joint . . . and how they reduce infiltration to a minimum and cut other sewage costs as well? Please write for folder TR-103A. Address Johns-Manville, Box 60, New York 16, N. Y.

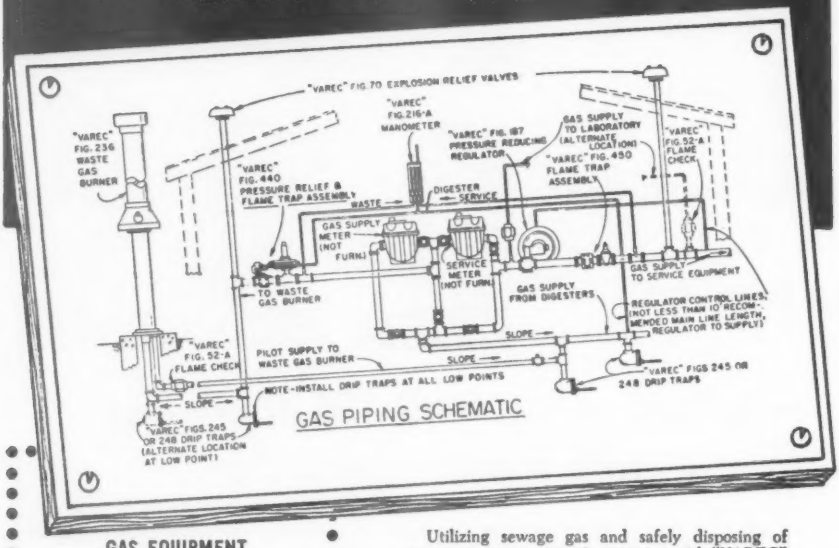
AND BUILDING SEWER PIPE, TOO!

Another J-M Asbestos-Cement Pipe, Transite Building Sewer Pipe, assures a tight sewer system throughout. Many municipal officials are insisting that house and building connections to their sewage lines be made with Johns-Manville Building Sewer Pipe to assure tightness throughout their systems. This pipe also has the same type of rubber ring sealed joint that is shown above.

*Reg. U. S. Pat. Off.

Johns-Manville TRANSITE SEWER PIPE

"VAREC" figures in *Your* SEWAGE TREATMENT PLANT DESIGN for SAFETY and GAS CONTROL


"VAREC" FIG. 70 EXPLOSION RELIEF VALVES
"VAREC" FIG. 236 WASTE GAS BURNER
"VAREC" FIG. 440 PRESSURE RELIEF & FLAME TRAP ASSEMBLY
"VAREC" FIG. 216-A MANOMETER
"VAREC" FIG. 187 PRESSURE REDUCING REGULATOR
GAS SUPPLY TO LABORATORY (ALTERNATE LOCATION)
"VAREC" FIG. 450 FLAME TRAP ASSEMBLY
"VAREC" FIG. 52-A FLAME CHECK
WASTE
DIGESTER SERVICE
GAS SUPPLY METER (NOT FURN.)
SERVICE METER (NOT FURN.)
GAS SUPPLY TO SERVICE EQUIPMENT
TO WASTE GAS BURNER
GAS SUPPLY FROM DIGESTERS
REGULATOR CONTROL LINES (NOT LESS THAN 10' RECOMMENDED MAIN LINE LENGTH, REGULATOR TO SUPPLY)
"VAREC" FIG. 52-A FLAME CHECK
PILOT SUPPLY TO WASTE GAS BURNER
SLOPE
SLOPE
SLOPE
NOTE-INSTALL DRIP TRAPS AT ALL LOW POINTS
"VAREC" FIGS. 245 OR 248 DRIP TRAPS
"VAREC" FIGS. 245 OR 248 DRIP TRAPS (ALTERNATE LOCATION AT LOW POINT)
GAS PIPING SCHEMATIC

GAS EQUIPMENT SPECIFICATIONS

a. **PRESSURE RELIEF AND FLAME TRAP ASSEMBLY**
"VAREC" Fig. No. 440

b. **FLAME TRAP ASSEMBLY**
"VAREC" Fig. No. 450

c. **FLAME CHECK**
"VAREC" Fig. No. 52A

d. **EXPLOSION RELIEF VALVES**
"VAREC" Fig. No. 70-1

e. **WASTE GAS BURNER**
"VAREC" Fig. No. 236

f. **DRIP TRAPS**
"VAREC" Fig. No. 245 (automatic)
"VAREC" Fig. No. 248 (hand operated)

g. **MANOMETERS**
"VAREC" Fig. No. 216A

"Varec" PROVED and APPROVED

Utilizing sewage gas and safely disposing of excess gas is an automatic operation with "VAREC" Equipment incorporated into your sewage plant design. With this equipment, accurate gas pressures are maintained in all service lines. As soon as the digesters make more gas than required for service, the pressure relief valve to the waste gas burner opens to permit safe burning of the excess.

Flame flashback to valuable equipment is prevented with "VAREC" Flame Traps and Flame Checks. The flame arresting element of the Flame Trap is designed to eliminate flame propagation of even more inflammable gases than encountered in sewage service. This element is the same as that used in "VAREC" Flame Arresters listed by the UNDERWRITERS' LABORATORIES for petroleum product storage.

Emergency explosion relief is accomplished with "VAREC" Explosion Relief Valves. These valves should be installed outside of any buildings.

An enlarged engineering drawing of the above gas piping detail will be sent upon request. If you design sewage treatment plants, write today.

THE VAPOR RECOVERY SYSTEMS CO.
COMPTON, CALIFORNIA, U. S. A.
Cable Address: VAREC COMPTON USA (All Codes)
New York • Boston • Pittsburgh • Chicago • Detroit • St. Louis • Houston
Tulsa • Casper, Wyo. • Provo, Utah • Los Angeles • San Francisco • Seattle

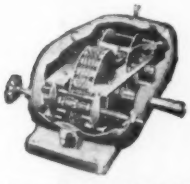
Available from authorized Sewage Equipment agents throughout United States and Canada

LINK-BELT sanitary engineering equipment is built to last with LINK-BELT components

IN municipalities and industrial plants all over the country, Link-Belt water, sewage and waste treatment equipment provides reliable, efficient service. There are two important reasons for this outstanding record—

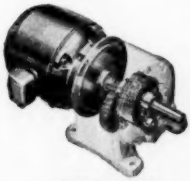
First, Link-Belt designs are based on broad experience and sound engineering . . . assure the finest in modern treatment techniques. Second, and equally important—Link-Belt equipment is built to the highest standards with Link-Belt power transmission and conveying components. This is your guarantee of long-life, high-efficiency operation.

The Link-Belt line includes coarse and fine screens, grit and sludge collectors for grit chambers and settling tanks, scum breakers for digestion tanks and sludge handling equipment. Our sanitary engineers will be glad to work with your engineers, chemists and consultants—help you get the best in modern treatment equipment. Call the Link-Belt office near you for complete information.



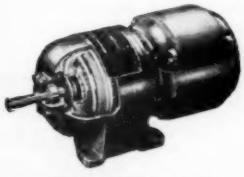
P.I.V. VARIABLE SPEED DRIVE

For positive, infinitely variable speed selection. Choose from 16 types, ½ to 25 hp, reduction ratios 6:1.



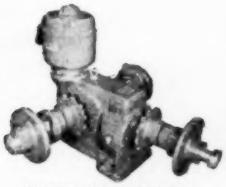
GEARMOTORS

Safe, compact, efficient. Output speeds from 6 to 280 rpm in standard line of double and triple reduction units.



ELECTROFLUID DRIVES

Hydraulic coupling combined with induction motor for smooth starting and shock load protection. Avoids "over-motoring."



WORM GEAR DRIVES

Suited to high-ratio reductions, with vertical or horizontal output shafts. Quiet, smooth, compact. Output rpm: 0.22 to 564.

ROLLER CHAIN

For positive power transmission at high or low speeds, coordinating rotation of numerous shafts. Long or short centers.

PROMAL CHAIN

This stronger, longer-wearing malleable alloy has toughness, strength, high yield point, high resistance to abrasion.

BELT CONVEYOR IDLERS

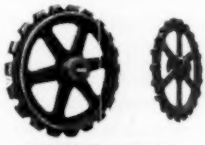
Husky, self-aligning roller bearings maintain alignment. Grease in-dirt out seals preserve lubricant longer.

SCREW CONVEYORS

Sectional flight and helicoid types. One moving part. Compact. No return run. Horizontal, vertical or inclined operation.

BALL & ROLLER BEARINGS

Full line of precision pillow blocks, flanged; flanged cartridge, cartridge, hanger, and take-up blocks for every need.



SPROCKET WHEELS

Teeth are accurately cast and hand ground to fit chain correctly. A type for every chain, a size for every requirement.

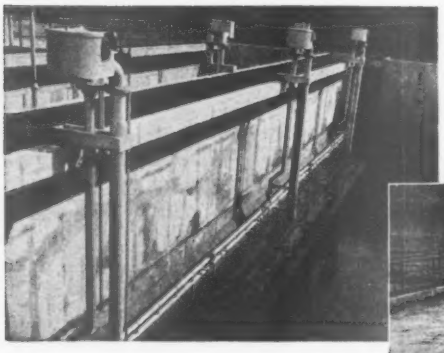
PEAK CAP BEARINGS

Water lubricated, Self-Aligning; prevent accumulation of sludge on all submerged bearings of Collectors.

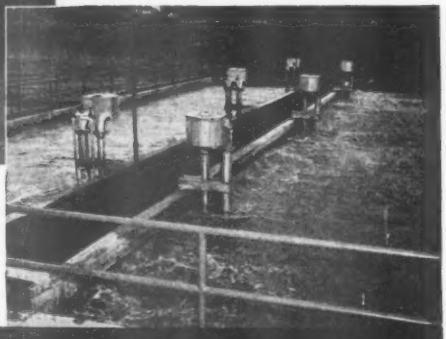
LINK-BELT

SANITARY ENGINEERING EQUIPMENT

LINK-BELT COMPANY: Plants: Chicago, Indianapolis, Philadelphia, Colmar, Pa., Atlanta, Houston, Minneapolis, San Francisco, Los Angeles, Seattle, Toronto, Springs (South Africa), Sydney (Australia). Sales Offices, Factory Branch Stores and Distributors in Principal Cities. 13,144-A



DIFFUSAIR installation at Kirkwood, Mo. Impingement nozzles and bowls are on headers at lower left side of tank.



DIFFUSAIR at Kirkwood, Mo. in operation showing effective "spiral flow" agitation and aeration of tank liquor.

impingement aerator **DIFFUSAIR**

FOR

SEWAGE

WASTE AND

WATER TREATMENT

PRE-AERATION . . .

ACTIVATED SLUDGE . . .

CARBONATION

The Impingement Aerator is a unit developed to accomplish more effectively and economically the diffusion of air as small bubbles to agitate and oxygenate aeration tank liquors.

The principle involved is the combining of a low velocity jet of tank liquor and large air bubbles within an open bowl-like impinger. The cavitation effect thus produced divides the air into smaller bubbles than those diffused from a No. 30 permeability porous tube. The amount and pressure of the impingement water is very low when compared with the progressive back pressuring of the blower that persists when other types of air diffusers are employed.

The impingement liquor is derived directly from the aeration tank mixed liquor, and is lifted with a simple air-lift unit from which 1/3 of the fine air is re-entrained and utilized for oxygenation.

The air is released along headers through 3/16 inch orifices in the impinger units and no air clogging is possible. No filtering of the compressed air supply is required since there are no fine diffusion pores to become clogged.

Write for Bulletin 17531

PROQUIP PROCESS EQUIPMENT

WALKER PROCESS EQUIPMENT INC.

FACTORY · ENGINEERING OFFICES · LABORATORIES

AURORA, ILLINOIS

STURDY, *long-wearing* INERTOL PAINTS

specified at

San Francisco Sewage Plant

Digester Tanks are equipped with fabricated floating covers protected completely with Inertol Paints. Pacific Flush Tank Floating Covers fabricated and erected by the Chicago Bridge and Iron Company. Contractor used Inertol Quick Drying Primer #626, and Standard Thick.

Primer #626 forms a tough inhibitive film to which paint bonds securely. Standard Thick, water and fume-resistant, protects steel surfaces submerged and subjected to extreme sewage gases.

Specified at Southeast Sewage and Treatment Plant by the Engineering Office of Clyde C. Kennedy

Engineer Kennedy's paint specialists couldn't guess about performance when choosing paints for San Francisco's new sewage plant. They needed coatings that would meet their high standards for elasticity, hardness, inertness and water-resistance. And that's why Inertol Paints—developed especially for sewage plant use—won their "O.K." The long-run economy assured by Inertol Paints has satisfied users in all parts of the country. And painting contractors D. Zelinsky & Sons found Inertol coatings easy to apply . . . *and* economical.

If your need is for a durable attractive coating, let an Inertol Field Technician help you find exactly what you're looking for. You'll find our free "Painting Guide" an invaluable aid, too. Write for your copy today—especially if you're a Specifications Writer, Design Engineer, Plant Superintendent or Contractor.

INERTOL CO., INC.

482 Frelinghuysen Avenue
Newark 5, New Jersey

27 South Park, Department 2
San Francisco 7, California

Chappell, Neb. obtains

Complete sewage treatment at low per capita cost

Aero-Accelator

provides high rate biological sewage treatment

Chappell, Nebraska, required complete biological sewage treatment. At the same time, Chappell's size (pop. 1500) would not allow a "blank check" budget. Fulton & Cramer, consulting engineers, solved the problem with an Aero-Accelator. This economical sewage unit installation provides rapid and sustained biological action with efficient clarification.

Griductor®

intercepts larger solids... reduces them by cutting and shearing

The Griductor protects Chappell's equipment from fouling and clogging. The simplicity of its straight channel installation was an added economy.

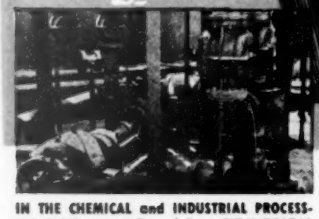
FOR MORE INFORMATION...
send for these detailed Infilco Bulletins
6510-AS *and* **5100-AS**

INFILCO

INFILCO INC. | *Tucson, Arizona*

Plants in Chicago & Joliet, Illinois

FIELD ENGINEERING OFFICES IN 26 PRINCIPAL CITIES



IN THE CHEMICAL and INDUSTRIAL PROCESSING FIELD A.C.F. Round Port CYLINDRICAL Plug Valves handle abrasive ladings, such as cement slurry, coal wash water, etc., without erosion—and have long life.

IN PETROLEUM and GAS INSTALLATIONS A.C.F. Valves give full-area flow with fast, positive shut-off.

IN SEWAGE PLANTS the A.C.F. CYLINDRICAL Plug shears obstructions on raw sewage lines . . . provides uninterrupted flow.

FULL PIPE SIZE AREA

A.C.F.'s Full Round Port, CYLINDRICAL Plug Valve has a straight level-through flow passage the same size and shape as the pipe itself! This means fast unobstructed flow of heavy or viscous ladings, solids in suspension, all liquids and gases.

And—there is full straight-through pipe area in A.C.F.'s Rectangular Port, CYLINDRICAL Plug Valve, too.

Investigate—you need "full pipe size area" valves for economical processing.

A.C.F. CYLINDRICAL FULL PIPE AREA PLUG VALVES

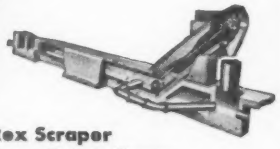
Write for Catalog 4-SI, American Car and Foundry Co. Valve Division, 1501 E. Ferry Ave., Detroit 11, Michigan

Representatives in 50 Principal Cities

these COLLECTORS PAY You OFF!

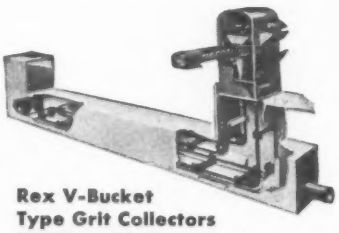
If your problem concerns separation of inorganic solids from liquids, you'll find Rex® Grit Collectors really pay off in longer service life and dependable, economical operation. They are especially designed for efficient operation under the extremely abrasive and corrosive conditions so common in this service. Tough, rugged Rex Z-Metal Chain is used throughout. Scrapers and buckets have hardened, renewable wearing shoes. Sprockets are of Rex Temperim® of double life design.

All Rex Grit Collectors have an exclusive grit conditioning feature by which improperly separated material, or material with excessive fines or organics, can be recirculated to the channel for resettling. For all the facts call your nearest Rex Field Sales Engineer or write for Bulletin 51-83. Chain Belt Company, 4606 W. Greenfield Ave., Milwaukee 1, Wis.



Rex Scraper Type Grit Collector scrapes grit from horizontal floor of the channel and drags it up incline for discharge into suitable receptacle.

Rex V-Bucket Type Grit Collectors for Shallow Channels. Both deep and shallow channel models have been installed for the protection of low level pumping stations.



Rex V-Bucket Type Grit Collectors for Deep Channels combine a scraper collector and a bucket elevator in a single unit.

REX CHAIN BELT COMPANY

Chain Belt COMPANY OF *MILWAUKEE*

Atlanta • Baltimore • Birmingham • Boston • Buffalo • Chicago • Cincinnati • Cleveland • Dallas Denver • Detroit • El Paso • Houston • Indianapolis • Jacksonville • Kansas City • Los Angeles Louisville • Midland, Texas • Milwaukee • Minneapolis • New York • Philadelphia • Pittsburgh Portland, Ore. • Springfield, Mass. • St. Louis • Salt Lake City • San Francisco • Seattle • Tulsa • Worcester

Export Offices: Milwaukee and 19 Rector St., New York City

Got the angle . . .

for BIG volume pumping?

You get a new high in service from Fairbanks-Morse *Angleflow* Pumps. They're designed for BIG volume pumping against moderate heads—sizes range from 8 to 54 inches . . . capacities up to 80,000 GPM.

You can move big volumes of sewage or storm water too, with *low* operating and maintenance costs. These Angleflow Pumps, with their wide, unobstructed impeller and volute passages, are especially suitable for handling debris-filled water.

For information, see your local Fairbanks-Morse Pump Engineer . . . or write Fairbanks, Morse & Co., Chicago 5, Illinois.

FAIRBANKS-MORSE

a name worth remembering when you want the best

PUMPS • SCALES • DIESEL LOCOMOTIVES & ENGINES • ELECTRICAL MACHINERY
RAIL CARS • HOME WATER SERVICE EQUIPMENT • FARM MACHINERY • MAGNETOS

DOUBLE-X Pipe Is Easily Laid

The above illustration shows an outfall sewer line at Dunedin, Florida, which was constructed of 20″ American Double-X mechanical joint pipe. It extends about one quarter mile into St. Joseph Sound for disposal of the effluent from the sewage disposal plant. The assembled pipe line was floated out from shore with a bulldozer supplying the thrust at the shore end.

Manufactured under rigid specifications in diameters 3″ through 48″, American Double-X pipe will stand the impact of heavy loads and gives complete job satisfaction. This pipe is manufactured in specific weights for specific laying conditions. You get the exact pipe your conditions require. American Double-X pipe is conveying water, gas, crude oil, gasoline, sour naphtha, sewage, salt brine—and in fact, just about everything that a pipe line can conceivably convey. It is conveying these products under operating pressures ranging from a few pounds to the square inch, up to pressures in excess of 100 pounds gas and 500 pounds liquid.

Being cast iron, American Double-X pipe enjoys an enviable reputation. Cast iron pipe has had over 300 years of service abroad and more than 100 years of service in the United States. It is satisfactorily serving in locations where especially severe external and internal corrosion conditions exist.

A complete line of fittings for use with American Double-X pipe is available including transition pieces for inter-connecting with other types of joints and pipe. Branch stocks of both pipe and fittings are strategically located for your convenience.

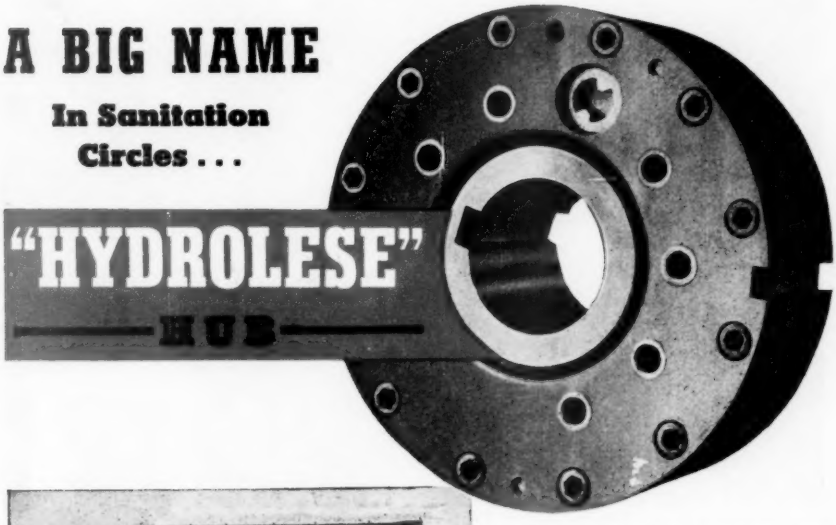
AMERICAN CAST IRON PIPE COMPANY

Birmingham 2, Alabama

Dallas Houston El Paso Pittsburgh Kansas City
Chicago Minneapolis New York City Cleveland
Los Angeles San Francisco Seattle Denver

A BIG NAME

In Sanitation Circles . . .



All collectors in service at the Hyperion Sewage Treatment Works, City of Los Angeles, are "HYDROLESE" protected.

Positive protection against overloads—elimination of troublesome shear pins . . certain when Jeffrey "HYDROLESE" Hubs are used on the countershafts with sprockets keyed to them.

The "HYDROLESE" Hub

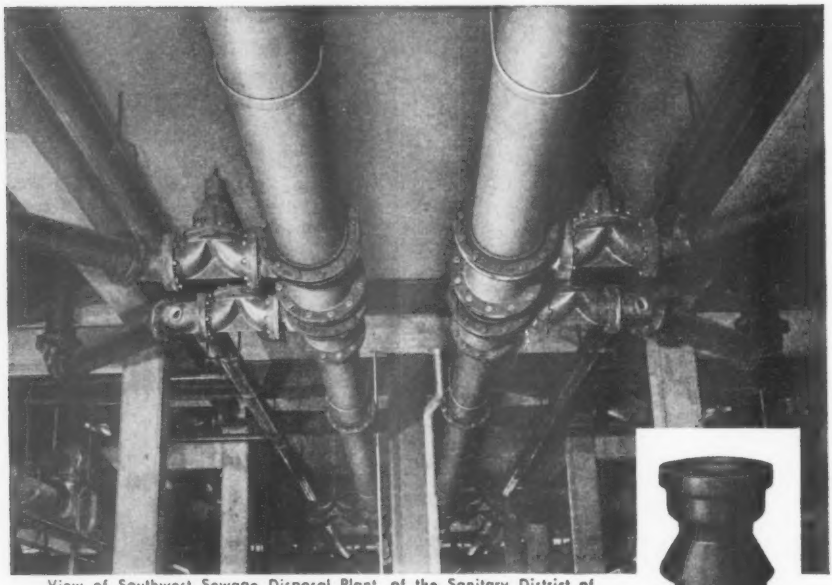
- Can be adjusted to meet various load conditions.
- Can be provided with visual warning of overload.
- Can be readily reset.
- Will not burn up.
- Will carry a definite torque load (Max. 20,000 lbs.).

Grit Washers
Grit Collectors
Cross Collectors
Spiral Conveyors
Sludge Collectors
Sludge Elevators
Scum Removers
Bucket Elevators
FLOCTROLS
Grinders
Chains
Bearings

This device has won wide favor in Sanitation circles—132 units used on the Los Angeles job. Send for complete information.

THE JEFFREY MANUFACTURING CO.
Columbus 16, Ohio
sales offices and distributors in principal cities
PLANTS IN CANADA, ENGLAND, SOUTH AFRICA

IF IT'S MINED, PROCESSED OR MOVED
. . .IT'S A JOB FOR JEFFREY!



View of Southwest Sewage Disposal Plant, of the Sanitary District of Chicago, Stickney, Illinois . . . where Clow Cast Iron Pipe was furnished to meet exact requirements.

Clow cast iron pipe, fittings, valves and specials for sewage plant replacements or new installations

• James B. Clow & Sons with their many years of experience as manufacturers of Cast Iron Pipe and Special Castings for Filtration and Sewage Disposal Plants know the difficult piping problems that continually face the sanitary engineer. Clow shops are completely equipped with the latest machinery. Clow's skilled workmen will produce pipe and specials to your exact specifications. Pipe can be furnished flange and flange, flange and bell, flange and plain end or with mechanical joint and plain end—in sizes 3 through 24 inches in laying lengths up to 18 feet.

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

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In Sludge Digestion... you need all 4!

Effective, two-stage, sewage sludge digestion involves far more than just a heated tank! There are four major — and interrelated — requirements.

Here they are . . . and here's what you need to meet them . . .

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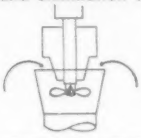
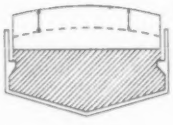


Calls for intensive mixing in the Primary by means of high-capacity propeller and draft tube.

2. Simplified Sludge Heating

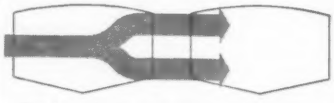
Requires an efficient heat exchanger of *simplified* design . . . without excessive and complex instrumentation.

3. Adequate Gas Storage



Demands a Secondary equipped with a movable, steel dome gas holder to even out fluctuations and insure a constant supply to gas utilization equipment.

4. Simplified Control



Requires a simple and automatic means of transferring sludge and liquor from the Primary to the Secondary at rate of feed.

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1952 Literature Review

A CRITICAL REVIEW OF THE LITERATURE OF 1952 ON SEWAGE, WASTE TREATMENT, AND WATER POLLUTION

By H. Heukelekian, *Chairman*, D. E. Bloodgood, G. P. Edwards, M. B. Ettinger, H. A. Faber, W. H. Gehm, D. D. Gold, R. D. Hoak, R. S. Ingols, P. W. Kabler, M. Katz, V. W. Langworthy, R. Manganelli, P. H. McGauhey, H. J. Miles, W. A. Moore, H. E. Orford, G. A. Rohlich, C. C. Ruchhoft, N. H. Sanborn, L. R. Setter, D. B. Smith, H. A. Trebler, and L. W. Van Kleeck

Committee on Research, Section A, Federation of Sewage and Industrial Wastes Associations

This is the second of two sections of the review. The first section, dealing with analytical methods, sewage, and radioactivity was published in the May, 1953, issue of This Journal.

INDUSTRIAL WASTES

Cannery

Treatment

Pilot-plant studies of filter design and operation for the biological filtration of sauerkraut and pickle wastes are reported by Haseltine (56). The author found that some factor or factors other than B.O.D. loading materially affect the B.O.D. reduction, but, if these factors could be eliminated, biological filtration would be at least as effective in treating such wastes as it is in treating sanitary sewage. It was concluded (a) that chloride concentrations of up to 5,000 to 6,000 p.p.m. had little if any effect on the biological efficiency, (b) that to provide maximum treatment of acidic wastes it is essential that the pH of the filter effluent does not fall below 6.6, and (c) that no correlation was found between recycle ratio and B.O.D. reduction. The B.O.D. of the recycle, rather than the volume of recycle, should be considered. The B.O.D. of the recycle should be less than 40 per cent of the total applied B.O.D.

Porges (103) studied the quantities of waste arising from potato chip plants. An average loss of 20 per cent by weight of potato is obtained, giving 65 lb. of B.O.D. and 120 lb. of suspended solids per 1,000 lb. of potatoes processed.

Sanborn (124) describes the use of spray irrigation as a method for the disposal of cannery wastes on the basis of a study of a number of installations. Of the problems discussed, that of providing an effective vegetative cover crop was found to be most important for the successful application of the spray irrigation method. Suggestions for utilizing disposal by spray irrigation in conjunction with lagooning are proposed for wastes produced during winter months. Nelson (86) describes, with a cost analysis, a spray irrigation system used to dispose of approximately 24 m.g. of waste water from the canning of peas and corn. The spray irrigation disposal of fruit

wastes at one canning plant is described by Hicks (61).

Eckenfelder (32) reports on a pilot-plant application of a high-rate biological sludge treatment of tomato and apple cannery wastes. The treatment process is conducted in three steps: (a) short-detention aeration of the raw waste in the presence of a large volume of an active biological sludge whereby organic matter is rapidly transferred to the sludge, (b) separation of the sludge in a clarifier, and (c) regeneration of the sludge in a "stabilizer" by aeration for a period of time sufficient to render the sludge capable of removing additional organic matter when returned to raw waste aerator. B.O.D. reductions of better than 85 and 90 per cent were obtained with tomato and apple wastes, respectively, with comparatively low total treatment plant retention periods.

Beidler (9) describes a combined screening, biological filtration, and lagoon treatment system for handling apple, cherry, and tomato wastes.

It had previously been reported that removal of traces of citrus peel oil was necessary to avoid inhibitory effects in continuous methane fermentation of citrus wastes. Wolford, Patton, and McNary (147) found naturally produced alcohols made possible complete removal of inhibitory peel oil.

The ferricyanide method of determining sugars was found to be applicable to the determination of total and reducing sugars in citrus canning wastes in the presence of domestic sewage (143).

Recovery

A method is described for producing a dry animal feed from the solid wastes from the canning of tomato juice or tomato products (38). Drying is done in a direct-fired rotary alfalfa drier. It is proposed that the press liquor be concentrated by submerged combustion and added to the press cake. Since the cost of recovery is expected to exceed the value of the feed produced, the process would be adopted only as a means of waste disposal.

Reviews

Rudolfs and Heukelekian (115) review the known methods for the treatment of cannery and other food wastes. Von Loesecke (137) reviews the methods for the disposal, treatment, and utilization of solid and liquid wastes from the citrus fruits industry. The treatment of citrus canning wastes and current experimental projects is reviewed by Wakefield (140). Wisniewski and Sherow (146) review the development of lagoons for cannery waste disposal and discuss the various odor control measures which have been tried.

Dairy

The interest in waste saving and waste utilization continues, but no really new ideas have been published during the year. Some new data on milk savings by Rugaber (121) confirm previous findings by others. Schwarzkopf (126) published additional data on milk can draining.

The preference for dairy waste treatment by activated sludge processes over other methods is continuing. Harding (54) gave new data in regard to a plant at Springdale, Conn. Hauer (58) gave additional data in regard to the Huntley and Chemung, Ill., plants. The plants themselves have been described previously by others. Thayer (131) discussed design features of aeration plants based on previously published data.

Hoover, Porges, and associates have continued their laboratory studies on dairy wastes. The oxidation of skim milk, casein, and lactose by aerated sludge was studied by measuring the evolved CO_2 both titrimetrically and manometrically (101). Under the conditions of their experiments, the CO_2 evolution was not markedly increased by the addition of $NaNO_3$, possibly because the high organic nitrogen content

of the mixture did not favor the growth of microorganisms capable of utilizing nitrate nitrogen (102).

By following the biochemical oxidation (continuous determination of the oxygen content by polarographic methods and by analysis of the microbiological sludge) the chemical equations for conversion of lactose, casein, and skim milk solids to microorganisms in an activated sludge process were established (64). A similar equation was established for the endogenous respiration of the sludge, so that finally a good quantitative picture of the biochemical oxidation of milk waste was obtained. This undoubtedly will prove helpful in designing new disposal plants and in improving the performance of existing installations.

They found (101) that the rate of endogenous respiration (aerobic autodigestion) of dairy waste activated sludge is very low. For instance, the sludge produced by the oxidation of 1,000 p.p.m. skim milk solids consumes 3 to 4 p.p.m. oxygen per hour. The same culture in the active growth stage consumes oxygen at a rate of 40 to 45 p.p.m. oxygen per hour. Consequently, it appears that if a plant is to be designed to "burn up" the excess sludge by aeration, one either has to recirculate a very high proportion of the sludge or provide relatively long retention in the aeration tank, or concentrated excess sludge has to be aerated for a long time in a separate tank. As a matter of fact, slow agitation might supply sufficient oxygen to maintain aerobic conditions in the separate sludge tank. It remains to be seen if this will be more economical than the use of conventional anaerobic digestion.

Pien (100) felt that if full advantage is taken of the oxidizing ability of streams, it is not necessary in most cases to treat dairy wastes, which, of course, is true if the dairy plants are small enough and the streams provide sufficient reaeration, which may be the case in the area considered. A wealth of experimental data is given on stream reaeration and auto-oxidation of milk waste containing various percentages of whey under simulated stream conditions. The importance of flow equalization and of keeping the waste cool and fresh before discharge to the streams is stressed. Suspended matter, if any, is sometimes removed by filtration through a layer of peat, which is frequently renewed. In cases where additional treatment is required, chemical precipitation with alum and lime is recommended with or without subsequent filtration through peat. It is difficult to see where this would be any simpler or cheaper than the aerated sludge treatment used in the United States, but conditions may be different.

Beet Sugar

Black and McDermott (14), in a broad review of the beet sugar waste problem, indicate that new techniques of sugar production with re-use of the process water should greatly aid in the amount of sugar produced while reducing the over-all cost of operation. Fleming (42) indicates that a modern plant can reduce its waste load, but that the increased cost of operation does not yield any net revenue from the increased sugar production. Niles and Frook (89) discuss the treatment of wastes from the production of monosodium glutamate (a concentrated Steffen's filtrate by-product). The wastes have high organic matter and chlorides. They will not digest alone, but may be digested with sewage sludge at the municipal treatment plant.

Chemical, Pharmaceutical

The waste treatment problems of the Willow Run, W. Va., and Pearl River, N. Y., plants of the American Cyanamid Co. are described (20) (136). The antibiotic wastes are strong, but are treated biologically. The sludge is high in ash, because of filter aid, and is dewatered directly. In Britain,

penicillin wastes (35)(142) have been successfully treated in the city sewage treatment plant by storing the wastes during the day and discharging the strong liquor during the night. Some recirculation of the filter effluent was found to be helpful, but enlargement of the plant was needed for handling the entire waste load. After laboratory studies (66), a trickling filter plant was built to treat penicillin and streptomycin wastes from the Upjohn Co. plant at Kalamazoo, Mich. The sludge is digested, but with difficulty and with elimination of the filter cell from the plant influent. Permissible digestion loadings are low.

Rostenbach (109) gives a review of the condition of the synthetic rubber industry with some comments concerning waste disposal from the various plants scattered over this country.

Laboratory studies by Eden, Freke, and Melbourne (33) on the treatment of waste waters containing hydrogen peroxide, hydrazine, and methyl alcohol have shown that lime, with copper ions as the catalyst, brings about mutual interreactions. These interreactions lead to large reductions in concentrations of the undesirable components.

In a review article, Hess and Carney (60) discuss the policies of the organic chemicals manufacturing industry. All the common devices for reducing stream pollution are used, for the organic industry started as a by-products industry. Waldmeyer (141) reports that wastes with formaldehyde are first lagooned to iron out concentration variations, then treated with activated sludge, and finally with a trickling filter. Purification amounts to 75 per cent by the oxygen absorbed test, whereas the B.O.D. appears to increase.

Taylor, in laboratory experiments (130), reports on the study of activated carbon, bromine, and ozone for improving a sewage with toxic industrial wastes. O.C. results indicate a considerable reduction, whereas B.O.D. tests were set up but not reported. Thus, it is not known whether the carbon or chemicals were effective in aiding biological treatment of the sewage.

Greene (50) discusses the problems of ammonia soda wastes manufacture. Present practice indicates lagooning, with eventual disposal of the liquid containing a rather large amount of sodium and calcium chloride. The yearly production of calcium chloride is many times the present yearly use of this salt. The Ohio location does not provide an underground formation for economical use of disposal wells.

As reported by Grindley (51) the disposal of the effluent in DDT manufacture required the change, in part, from calcium to sodium hydroxide to eliminate an excessive sludge problem at a small sewage disposal plant. More calcium ions were removed with sodium carbonate and all DDT itself was carefully precluded from the drains. Some concentrated acids had to be tank trucked to an estuary; chlorine in the waste water was recovered for sale as domestic bleach. Reports of wartime experience in handling wastes from a shell loading plant using di- and trinitrophenol are given by Wilkinson (145). The trinitrophenol (picric acid) is less toxic than the dinitrophenol, but 20 p.p.m. of the mixture of shellite could be tolerated in the town's sewage treatment plant.

Kremer (69) reports that wastes from a metalworking plant manufacturing Army tanks require a high degree of treatment. Cyanides are alkaline chlorinated, the cutting oil emulsions being broken with ferric sulfate at pH 6.5.

The General American Transportation Corp. (52) must clean out tank-cars between each use of the car. Steam is used in cleaning the cars. The oils and acids are removed by adsorption on powdered soft coal. A trickling filter is used as the last step. A report of the first year of operation (53) indicates that results have been

satisfactory. The production of commercial sulfuric acid from the treatment wastes of iron and titanium pigment plants is described by Bartholomew (8). The iron is roasted to ore and the acid is recovered for re-use.

Because of the high cost of treating waste from a small percentage of the corn processed by the American Maize Products Co. (135), the process of handling corn was changed at a cost of $850,000. This large investment will be largely recovered by the increased yield of the corn to be sold and the reduced cost of treating the waste load.

Fermentations

Mixed distillery wastes consisting of three-fifths slop are being sprayed from rotary gun-type distributors at the rate of 3,780 g.p.a.d. over a deeply plowed ground in France. The seepage into the stream did not create pH, turbidity, or odor problems and did not affect the fish life (107).

A review of American practice, by Boruff (19), shows that most of the concentrated fermentation wastes are used for feed, either directly or after drying. The dilute wastes are treated as necessary in high-rate aerobic treatment devices. With dilute distillery wastes, Davidson and Brown (27) report that anaerobic digestion for 10 to 20 hr. is very effective in reducing the B.O.D. by an average of 80 per cent. Trickling filter plants installed by the company at several plants have been effective, but too expensive.

Packinghouse

Mohlman and Hill (79) have reviewed the status of the industrial wastes from packinghouses.

Textile

Studies on the activated sludge treatment of flax retting wastes, with 20-day B.O.D.'s of 5,000 p.p.m., have been reported (91). The retention period in the aeration tank was 36 hr. Nemerow (87) describes the dyes used in the industry and tells about the other chemicals used in the process of dyeing. He describes the method of approach to the problem of the Salisbury Cotton Mill, Salisbury, N. C. The treatment plant designed as a result of the study consisted of mechanical bar racks, combination preaeration flocculation and primary clarifier, chemical feed and flash mixer, high-rate trickling filter, secondary flocculation and sedimentation, final chlorination, sludge digestion, and sludge nitrifying aeration basin to receive secondary sludge and digester liquor with return of the material to the filters.

Sabnis (123) reports on preliminary experiments on the treatment and disposal of concentrated kier liquor and dye waste waters, saying that recovery of materials and re-use of liquors is not economical. The statement is made that iron salts and calcium chloride are satisfactory for removal of color and suspended solids.

Bogren (18) gives information on the characteristics of cotton finishing wastes and describes the layout of trickling filters and secondary settling to supplement the present facilities of the Sayles Finishing Plants mill at Saylesville, R. I.

The "acid" waste from a viscose-rayon factory is treated by neutralization and settling and the alkaline sulfide wastes are treated by biofiltration. The two treated effluents are mixed and chlorinated before discharge (65).

Nemerow (88) states that the main dyes used in the textile industry are (a) direct colors, (b) sulfur colors, (c) vat colors, (d) acid colors, (e) developed colors, (f) naphthanol colors, and (g) acetate colors. He gives the main constituents and the pollutional characteristics of each of the dyes, and further says that textile wastes must be equalized, neutralized, discharged in proportion to sewage in municipal

systems, decolorized, and have the organic solids removed before discharge to the receiving stream.

Foote (43) relates that at New Haven, Conn., the waste waters from a dye plant were found to have a very high chlorine demand due to the sodium sulfite and the sodium hydrosulfite used as reducing agents in the dye.

Tanning

Harnly (55) has listed the location of the 443 tanneries in the United States. A review of the waste problems of the tanning industry is given and, in addition, methods for process changes that will reduce waste quantities.

A tannery at Bolivar, Tenn. (25), mixes wastes with domestic sewage before sedimentation and eventual discharge. Ferric sulfate is used to control odors and some chrome liquors are recharged and re-used.

Henning (59) listed stream pollution legislation that has an influence on the operation of tanneries. Thorstensen (132) has indicated that there are ways that the tanning industry can prevent stream pollution.

Foster (44) describes the pretreatment of the waste from a chrome tannery in Scotland by aeration and the addition of coppers prior to discharge to the city sewers.

Wool Scouring

McCarthy (75) reported on the use of calcium chloride in the treatment of wool scouring wastes and others containing soaps or syndets. The results of full-scale operation of several plants are given. In general, B.O.D. removals of full-scale operation are better than in the original laboratory experiments, often averaging more than 50 per cent removal. Most mills prefer to use calcium chloride alone instead of a combination carbon dioxide and calcium chloride treatment, even though chemical costs are higher. Gernet (46) reviews patented chemical and mechanical methods of obtaining wool grease from scouring liquor and for cleaning of the liquor for re-use.

Evans and Winsor (39) have reported that wool scouring wastes produced by synthetic detergents can be cracked or reclaimed at the factory by adding a solution of aluminum sulfate prior to acidification.

Brines

Orsanco (92) has published a special report on pollution of the Muskingum River by two companies processing natural brines on the headwaters. A survey disclosed that the brines affect the entire length of the river, and that the chloride concentration fluctuates widely. The Muskingum raises the chloride content of the Ohio River to 47 from 21 p.p.m., equivalent to about 1,000 tons per day. If uncontaminated by brines, the Muskingum could be used as a source of water supply by a population of 125,000. Although there has been considerable research on the problem, no practical solution has been found. Orsanco recommends further research by the companies involved, possibly in the direction of basic process changes. Either electrolytic production of caustic soda and chlorine or subsurface disposal might be feasible.

Oil Refineries

The history of waste treatment in the refining industry was reviewed by Weston (144). The American Petroleum Institute has (a) sponsored research, which resulted in a standard design for gravity separation of oil from water; (b) investigated the effects of refinery wastes on bacteria; and (c) published a manual of good practice in handling chemical wastes. Weston's paper contains a detailed flow sheet of refinery waste waters and seven diagrams of recovery processes. It was emphasized that waste treat-

ment is now considered a basic factor in design of all new installations.

Gothard and Fowler (47) outlined the pollution abatement program of Sinclair Refining at Indiana Harbor, Ind. The principal items were (a) separation of sanitary sewage from refinery waste, (b) minimizing wastewater volume by using cooling towers and recycling water, (c) installation of API separators for the reduced water volume, and (d) treatment of heavily polluted water at its source. The API separator has been recovering 638 bbl. of oil per day for an average removal of 97.3 per cent. Process waste water has been kept to a minimum by economy campaigns, plus some remodeling. Effluent volume averages 5,000 g.p.d.; it would be 100,000 g.p.d. without corrective measures.

The theory of gravity separation of oil was discussed by Simonsen (127). The so-called "basic" chamber of the API design depends upon an oil particle 0.02 cm. in diameter rising to the surface by the time an influent unit of water reaches the outlet. In practice, a basic chamber should be followed by a secondary chamber 1.4 times as long, if maximum separation is to be attained. Sohio, at Toledo, installed two series of 10 secondary basins in parallel, with both series supplied by an influent channel that serves as a primary separator. This has worked well and avoids use of the film rupture chamber, which has often been a source of operating trouble.

Soluble and insoluble cutting oils, and steam cleaning and paint spray solutions are successfully treated as outlined by Solms (129). Emulsions are broken with $Fe_2(SO_4)_3$, plus H_2SO_4 to maintain low pH. Oil and sludge are separated in a clarifier. Effluent is treated in a Cyclator with $Fe_2(SO_4)_3$, lime, and activated silica for final clarification, and finally is chlorinated. Bloodgood and Kelleher (17) reported results of a basic study of emulsion-breaking with lime. They found that oil can be removed from hard-water emulsions with lime alone. Flocs formed in place, such as $CaCO_3$ or $Fe(OH)_3$, can absorb all the freed oil if sufficient chemicals are added.

A bench-scale study of an activated sludge process for treating refinery effluent was described by Coe (24). Using 1,500-ml. aerator-settlers, and starting with domestic sewage to which the waste was added in gradually increasing proportion, he used feed rates of 1.4 to 6.3 ml. per hr., 0.1 cu. ft. of air per min., and aeration periods of 4 to 18 hr. at room temperature. Condition of floc was judged by sludge volume index and rate of increase of floc in the aerator. An index of 50 to 125 ml. per g. was usual; values above 125 indicated overloading and/or low pH of feed. Porous glass discs were used in aerators; frothing was controlled with D-C Antifoam A. Removals from wastes averaging 100 p.p.m. phenol, 1,100 p.p.m. B.O.D., and 500 p.p.m. O.C. were 90 to 95 per cent, 90 to 95 per cent, and 73 to 77 per cent, respectively. It was possible to operate without sludge removal because rates of floc growth and deterioration were roughly equal and small. Blowing refinery effluent without sewage for about two months yielded a readily settleable floc. Degnan, Merman, and DeMann (28) found that catalytic cracker water, spent caustic, and methyl ethyl ketone could be successfully treated in bio-filters if proper temperature, loading, and recycle rate were maintained. At 85 to 90° F., 80 to 85 per cent of phenol and B.O.D. could be removed, but removal rate decreased with temperature, dropping to 15 per cent at 55° F. B.O.D. removal increased with concentration of feed, becoming constant at 62 per cent for 350 p.p.m.; C.O.D. (O.C.) curves were similar. Increased phenol concentration reduced removal; at 40 p.p.m. it was 48 per cent, at 200 p.p.m. 9 per cent. A 4:1 recycle rate gave the best practical result. Oil below 100

p.p.m. and sulfide below 10 p.p.m. had little effect. Biehl (10) briefly reviewed methods for treating phenolic wastes, and found all less satisfactory than multi-stage countercurrent liquid-liquid extraction (11)(12). Using a Scheibel column with a 75–25 mixture of aromatic and paraffinic hydrocarbons in a 2:1 solvent/waste ratio, he reduced phenol in catalytic cracker accumulator water to 0.2 p.p.m. from 200 p.p.m. Spent solvent was regenerated in an H_2S stripper and returned to the column. Since flow of waste and solvent is continuous and adjustable, the equipment is adaptable to various rates and ratios.

A process for making $(NH_4)_2SO_4$ from acid sludge and waste NH_3 was described by Fox (45). Sludge and ammonia are fed continuously to a reactor discharging to an oil separator from which the clear liquor flows to an evaporative crystallizer. Steam and H_2S pass from the reactor to a condenser; the H_2S goes to a Claus sulfur recovery plant. When acid in the sludge exceeds about 30 per cent no heat is needed by the crystallizer, which is operated at 150° F. and 3 p.s.i. (abs.) Vacuum is held constant by controlled condensation of evaporated water. Cold mother liquor from the sulfate filter is recycled to the reactor to absorb heat from the exothermic reaction. This process eliminates a disposal problem, conserves natural resources, and provides a new source of revenue.

Coking

A detailed account of the origin of gas works liquor and the pollutants it contains was published by Badger (6). In Britain, controlled discharge of liquor to sewage treatment plants is considered the simplest and most satisfactory disposal method. The liquor should be low in thiocyanates and polyhydric phenols, and ammonia, sulfides, and cyanides must be removed by distillation. In some cases additional purification may be necessary. In general, spent liquor of reasonable quality can be oxidized with sewage if it does not exceed about 0.5 per cent of the sewage flow. A smaller proportion of crude liquor can be handled because of the extra load of ammonia and sulfide.

The results of a cooperative pilot-plant study of oxidation of ammonia still waste with chlorine, chlorine dioxide, and ozone were reported (93)(22). The plant was designed to treat 2 g.p.m. of waste continuously, or 350-gal. batches. The principal findings were as follows: Phenol can be oxidized by any of the three agents, and local conditions will decide which is best; substantial reductions occurred with small dosage of each oxidant, but increasingly larger amounts were required as phenol was reduced further; B.O.D. and O.C. were reduced 60 per cent by each agent; phenols represent only part of the oxygen demand of still waste; temperature must be below 45° C. for chlorine, to avoid formation of chlorates; chlorine requires pH of 7 to 10; with chlorine, ammonia must be completely destroyed before phenols will be attacked, and all phenol must be oxidized to prevent chlorophenol odor; chlorine causes an increase in chlorides in direct proportion to amount used, chlorine dioxide causes a small increase, ozone none. The report contains three schematic flow sheets and five tables of data.

A large-scale experiment at Gary (74) demonstrated that ammonia still waste can be successfully treated with sewage by activated sludge. The test was started with a uniform load of 200 lb. phenol per day in 43,000 gal. of waste; flow was gradually increased until full load from the U. S. Steel coke plant was handled in 40-fold dilution with raw sewage. Although the run was made during the winter months and the phenol load fluctuated over a wide range, an average of 97.3 per cent removal was attained. It was

concluded that up to 25 p.p.m. of phenol in sewage could be completely destroyed, provided substances toxic to aerobic process did not build up; solids in mixed liquor and air supply must be increased; sludge return rate must be raised if air is to be kept to a minimum. Mogelnicki commented that the most significant aspect of the work was industrial-municipal cooperation. On the basis of work by Dow Chemical, he did not agree that higher solids were needed or that more air had to be used. Blackburn, Tomlinson, and Summers (16) summarized an investigation by Water Pollution Research covering disposal of spent gas liquors on trickling filters, and separation of the liquor into fractions to determine the effect of each on sewage treatment. Addition of spent liquor to sewage in excess of 0.5 per cent by volume caused a significant deterioration in effluent chemical quality and some increase in color in a large-scale test. Trials with fractions of crude liquor were made on small filters (1-ft. diameter). They found greatest deterioration in effluent quality with fractions containing (a) thiocyanates, ammonia, and organic substances not extracted by methyl isobutyl ketone, and (b) carboxylic and "humic" acids. Polyhydric phenols caused noticeably lower effluent quality (as measured by oxygen absorbed from permanganate) than monohydric phenol, but effect of both on B.O.D. was similar.

Cummings and Morton (26) compared the Metasolvan and Phenosolvan processes with glycerol, triethylene glycol, and methanol for phenol extraction. They report that non-aqueous extraction of hydrocarbons with glycerol achieves most complete separation of phenol. With glycerol in 1:1 ratio, two theoretical stages will reduce phenol to 0.25 per cent from 25 per cent, yielding up to 99 per cent pure phenol. The paper gives ternary solubility data and diagrams for glycerol and triethylene glycol with phenol and hydrocarbon at 20°, 40°, and 60° C. A questionnaire (3) disclosed that several new laws for protection of waterways in Britain were expected to be enforced strictly, and that the same situation may develop in France and Belgium. Elsewhere abroad, such legislation as exists is not very effective. Dephenolizers are extremely rare except in Britain, where they are necessary to reduce the load on sewage plants or to prevent stream pollution.

In comments (15) on a paper by Cooper and Bouch (Ref. 36, Review for 1951) proposing destruction of toxic substances in still waste with HNO_3 and recovery of 90 per cent of the acid for re-use, the importance of the work was recognized, but its economics and technology were questioned. Loss of HNO_3 by nitration of phenolics, and production of HCN were cited. It was suggested that destruction of compounds in ammonia liquor was wrong: recovery methods should be studied instead. It was thought that disposal to sewage plants was not a good answer, because of tendency to concentrate gas manufacture in a few areas, with consequent overloading of treatment works. It was pointed out that oxygen consumed reduction was not synonymous with purification. Cooper responded that both absorption of HNO_3 by phenols and high residual acidity could be minimized.

Although many trials of gas liquor as a fertilizer (2) have been made during the past 15 years, transportation costs and operating difficulties prevented any advance until recently. The problem of rapidity, accuracy, economy, and timing of application appear to have been solved. Use of 400 gal. per acre on grassland from February to October gave high yields of grass with increased protein and rapid growth. The liquor persists in the soil after a wet season better than ammonium sulfate. Hazards to health in the coking industry were discussed by Ragan (104), who found potential

danger of pneumoconiosis from coal and silica dust, cancer from exposure to aromatics, dermatitis from tar and its derivatives, benzene narcosis, and cancer of the bladder from napthylamine, aviline, and benzidine. Only a small proportion of workers are affected by these disorders, but all are preventable. Presence of phenol in waste water (1) from reclaiming rubber by digestion with NaOH and plasticizers resulted in a successful treatment process. The waste is coagulated with copperas and settled, the pH is adjusted to 7 with lime, and the liquor is pumped through the injector of a chlorinator. Phenols are completely destroyed and the waste is partly decolorized. Effluent is combined with an acid waste to neutralize it. The plant cost $90,000 and treats 60,000 g.p.d. of alkali and 250,000 g.p.d. of acid waste. Final effluent is passed through an upflow limestone bed.

Plating

A report was made by Zabban, Dodge, and Walker (149) on progress under Project No. 10 of the American Electroplaters Society. Dodge and Zabban (30) presented details of Part IV of Project No. 10 on batch volatilization of HCN. The principal conclusions of the paper are that more than 99 per cent of simple cyanides are present as HCN as pH 6.5, the zinc complex begins to break down at pH 6.9, and the copper complex at pH 4.5. Plating solutions should be acidified to pH 3.5 to insure volatilization of all cyanide in the shortest time. The paper contains 7 tables of data and 19 plots. The same authors (31) published an addendum to Part III, which points out that where Rochelle salt is present in solutions treated with hypochlorite in the absence of sufficient calcium, a tartrate complex prevents complete precipitation of copper. Where Ca stoichiometrically equivalent to tartrate is present, precipitation is complete. If carbonates or other substances forming insoluble compounds with Ca are present, the Ca requirement is increased in direct proportion. Eden and Wheatland (37) studied the effect of temperature and hypochlorite on hydrolysis of cyanogen chloride in alkaline solution. Hydrolysis appeared to be a pseudo-first-order reaction at pH 11. The velocity constant at pH 11 in solution of 0.15 ionic strength was 530 l. per mol min. at 25° C.; the change in rate between 0° and 30° C. was in agreement with Arrhenius' equation for a reaction with an energy of activation of 12,400 cal. Hypochlorite accelerated the reaction at pH 11, the increase in velocity constant being proportional to the concentration of available chlorine.

When the load increased on a plant using gaseous chlorine for destruction of cyanide, Roy (110) found an advantage in using sodium hypochlorite with a catalyst instead. Increased reaction rate, continuous operation, and proximity of a source of hypochlorite were favorable factors. It may be possible to eliminate the (unidentified) catalyst. Eden, Hampson, and Wheatland (34) observed that when an excess of hypochlorite is used to destroy cyanide, the excess is not taken up directly but agrees closely with the amount needed to form the nitrate that appears in the products of the reaction. Cyanogen chloride was completely removed at pH 8.9 to 9.9 from a solution originally containing 30 to 45 p.p.m. by adding hypochlorite equivalent to 0.5 g. atom per g. mol cyanogen chloride; at pH 8 or less it persisted a long time if only a moderate excess of hypochlorite was present. Simple cyanides, zinc, and cadmium complexes were destroyed completely at pH 11 if 2 g. atoms of available chlorine are added per g. mol of cyanide; potassium nickelocyanide was not removed in 2 hr., even with a large excess of hypochlorite; potassium ferrocyanide was not oxidized by hypochlorite in strongly alkaline solution. They determined

that 50 mg. CNCl per c.c. of air was the maximum concentration tolerable by man without harm. This concentration would be found in air in equilibrium with a solution containing 2 p.p.m. CNCl at 20° C. Alkaline chlorination was decided upon by Carmichael (21) to destroy 25 p.p.m. of cyanide in a solution containing H_2SO_4, $(NH_4)_2SO_4$, and some organic material. Because the organic matter could not be destroyed without first consuming all the NH_3, it was eliminated at its source. The chlorine demand was then found to be within 10 per cent of the theoretical requirement. A list of equipment and instruments is given for a continuous plant. Lose (72) used aeration to reduce the cyanide content of a waste water to 1 p.p.m. The waste is then stored in a large lagoon, from which it discharges through an automatic alkaline chlorination plant.

Keller, Cupps, and Shaw (68) described waste recovery in a plating shop where only 5.7 per cent of the chromium used was actually deposited on bumper bars, due to excessive dragout. By using air jets to blow off initial rinse water, and water sprays plus air jets following the plating tank, loss was greatly reduced. The stock was rinsed in a tank that does not overflow, with water from this tank supplying the water sprays. Drainage from the spray tank is concentrated by evaporation and returned to the plater. The recovery plant cost $10,000, but it paid for itself in three months, even though operating costs are $500 per month. Hathaway (57) described a glass-lined steel evaporator used to concentrate rinse water from a chromium plating line. The concentrate is returned to the plater, the condensate to the rinse tank. The evaporator is operated under 26 in. Hg induced by a steam exhauster requiring 415 lb. of steam per hr. at 75 p.s.i.

Copper and brass pickling results in considerable rinse water of variable composition. McGarvey, Tenhoor, and Nevers (77) prefer using ion exchange in the hydrogen cycle for recovery of Cu and Zn, because H_2SO_4 regenerant can be re-used in the pickler. They note that the major factor influencing recovery of these metals is the relative amount of Ca and Mg in the raw water. Where elimination of the metals without recovery is desired, the sodium cycle should be used because of higher capacity of resin, lower sensitivity to total hardness, more complete removal of Cr, and lower acidity. Details of the investigation are given, including economic evaluation. Fadgen (40) reviewed the fundamental basis of ion exchange and gave detailed data for the economic analysis of recovery of Cr, Ni, and Cu. In another paper (41) he discussed a variety of practical problems where ion exchange is used to treat wastes containing Cr, Ni, Cu, and a number of anions. Paulson (97) (98) (99) points out that until recently ion exchange could not be used for recovering Cr from anodizing waste water because the resins were not sufficiently resistant to oxidation. An aircraft manufacturer now operates a recovery plant on water containing 50 to 70 g. CrO_3 per l. at pH 0.7 to 0.9. Each day a portion of the bath is passed through a high-capacity cation exchanger, which replaces the dissolved Al with H +; the effluent is returned to the anodizer. The paper gives many details of the operation. Armstrong (5) discusses another installation of the same type, and reports a saving of $1,700 per shift per year.

McGarvey (76) described the characteristics of a number of exchange resins and gave details of operation on several anion and cation recovery problems, with data on capacities and economics. Reents and Stromquist (106) reviewed recovery of chromate by ion exchange, and reported experimental data showing that recovery from rinse water could be accomplished for roughly one-half the cost of disposal. They

state that recovery of Ni is simple compared to chromate, but that it is not economically worth-while to attempt recovery of Cu and CN by ion exchange. Graham and Pinkerton (48) discussed waste treatment from the electroplater's viewpoint, and described the great diversity of operations in the plating industry. They said that more information is needed on practical analytical controls and on the effect of plating waste on sewage treatment.

An actual plan for remodeling a plating shop was presented by Lancey and Hanson (70). The plan is based on Lancey's "integrated waste treatment principle" (cf. ref. 86, Review for 1951). Orsanco (94) has published a manual describing practical methods for reducing dragout losses, for effective rinsing, preventing leaks and losses, and salvage of spent baths. Sanders (125) described conversion of a former domestic sewage treatment plant into one for treating waste water containing emulsified oils, floating oil, solvents, CrO_3, and small amounts of a number of metal ions. Murdock (81) recalled that the Naugatuck river contained 10 to 25 p.p.m. Cu in 1914. He found that use of this water accelerated oxidation of reclaimed rubber. One-third of the copper and brass products made in the United States are manufactured in this valley, and there are about 100 small plants that process non-ferrous goods. Waterbury has contracted for a primary sewage plant with non-biological sludge disposal because the high copper content of the sewage would prevent digestion.

Pickling

The mechanism of the neutralization of pickle liquor was studied by Levine and Rudolfs (71), who titrated the liquor with NaOH and found four separate reactions: formation of $Fe(OH)_3$ below pH 4, acid sulfate, $Fe(OH)_2$ between pH 6 and 8, and normal sulfate. Na_2CO_3 and NaOH are most expensive, high-calcium and dolomitic limes least expensive neutralizing agents. Bound water of hydrous oxides determines the settleability and final volume of the sludge. Solids content of the sludge is important in settling; it varies with reactivity of the lime. The sludge contains enough voids to assimilate all reaction products without an increase in volume. Minimum sludge volume is produced by oxidation, and this results in cost saving. Parsons (96) discussed supersaturation with $CaSO_4$ in lime neutralization. He defined after-precipitation as material settling after the first hour, and concluded that high-calcium and dolomitic limes may produce after-precipitation but the amount is greater with high-calcium. Scaling becomes progressively more intense by over-treatment with high-calcium lime. The scale formed by either lime at pH 4.2 to 5 is soft enough to be removed by hydraulic scour. After-precipitation can be controlled or eliminated by dilution prior to final sedimentation. Riegel (108) said that water conservation is essential at Fontana because the steel mill is not located on a stream to draw water or discharge wastes. Raw water is treated (with sludge recirculation), filtered, and recarbonated for potable supply. Industrial water is supplied through separate systems and conserved with cooling towers. Blast furnace washer water is used to cool slag. Each group of mill operations is equipped with cooling-tower systems that are interlocked for flexibility. Sewage is treated by two-stage bio-filtration, the effluent being chlorinated and returned to the industrial water system. Pickle liquor is neutralized with lime, settled, and supernatant flows to the sewage plant chlorination basin. Waste water from coke ovens is used to quench coke. These measures are expensive, but permit steelmaking with 1,400 gal. per ton instead of the normal 65,000 gal.

The effect of temperature on neu-

tralization of pickle liquor in upflow limestone beds was investigated by Eden and Truesdale (36). With solutions containing 2,000 to 10,000 p.p.m. H_2SO_4 at 4° to 30° C., the maximum amount of acid neutralized increased rapidly as the temperature decreased. It appeared that the extent of neutralization was governed by solubility of the metastable $CaSO_4 \cdot 1/2\,H_2O$. Inactive limestones could be reactivated with solutions of ammonium acetate or thiosulfate, or of sodium hexametaphosphate. With solutions containing 3,050 p.p.m. H_2SO_4, 8,400 p.p.m. Fe^{++}, and 30 p.p.m. Fe^{+++}, neutralization was almost equal to that with acid alone. When Fe^{+++} was increased to 170 p.p.m., neutralization was less effective. With solutions of 2,790 p.p.m. H_2SO_4 and 320 p.p.m. Fe^{+++}, all free acid and some from hydrolysis of $Fe_2(SO_4)_3$ was neutralized. Reed, Pettit, Cubberley, Lewis, and Harper (105) participated in a symposium on pickle liquor neutralization. Reed noted that no general solution to the pickle liquor problem had been evolved, in spite of a large amount of time, effort, and money spent on it. He suggested that profitable recoveries were unlikely, and the best that could be hoped for was a reduction in the cost of treatment. Pettit described the Armco neutralization system, in which all liquor and rinse water is collected and pumped to five reaction tanks in series at flow rates of 450 to 1,100 g.p.m. Lime is added to the first tank (and to the second, if needed) and the contents of each tank are recirculated by centrifugal pumps. Slurry from the last tank is pumped to a lagoon at pH 8.5 to 9, maintained by pH control. The cost of treatment equals the original cost of the acid. Cubberley and Lewis outlined a neutralization plant in which the liquor is pumped alternately to two agitated tanks. A full tank is treated with an excess of dry hydrated lime. At pH 9, it is allowed to settle overnight. The supernatant is decanted to a holding tank for pH adjustment, if necessary, then discharged to a stream. Sludge is carried by a screw conveyor to a rotary vacuum filter, from which it is trucked to a dump. Harper described the contractual arrangement by which he takes pickle liquor from steel mills, hauls it to his plant, and treats it with pulverized limestone, using a turbo-mixer with air injection. Slurry flows to a small lagoon where cement dust is added to complete precipitation of iron, and then passes to a final lagoon.

A continuous pilot plant for making iron oxide pigments from pickle liquor was described by DeWitt, Livingood, and Miller (29). With relatively simple controls it has been possible to make excellent reds, yellows, and intermediate shades. Red oxides are made by mixing proper proportions of iron salt and precipitant and recirculating in a reaction drum at predetermined pressure and temperature. Yellow oxides are made either by simultaneous solution and oxidation of iron from scrap, or by slow oxidation of Fe^{++} solution with no scrap or Fe^{+++} present. A plant to produce 8 tons per day of either oxide would cost $150,000; profit would be ample to amortize such a plant in 18 months. Rusher and Blum (122) investigated production of copper sponge from pickle liquor sludge by displacement with zinc. They found 4 to 7 per cent H_2SO_4 necessary to deposit the copper as sponge through evolution of hydrogen; more acid consumes the zinc unnecessarily. Sponge-like Cu of 99 per cent purity was obtained by slow flow of solution past the Zn surface. The sponge must be dried rapidly to preserve high activity for catalytic applications.

Production of iron, steel, coke, slag, and blast furnace dust was reviewed by Hoak (62). Coke oven operation and waste disposal were outlined, and details of some of the more promising pickle liquor recovery processes were given. The same author prepared a

manual of pickle liquor treatment for Orsanco (63). Neutralization processes were described in considerable detail, and those by-product recovery processes that are technically feasible were discussed.

Recovery processes for HCl pickle liquor were reviewed by Chivers (23), who found them all to be uneconomical and concludes that the liquor can best be used as a coagulant at sewage works. He reported that the growing practice in Britain is to concentrate sulfate liquor, separate copperas, and recycle the recovered acid. Conversion of copperas to fresh H_2SO_4 is regarded as uneconomical, except on a very large scale. A simple type of continuous plant for copperas recovery is described. Tiddy and Cooper (133) patented a process for producing ferric oxide from pickle liquor by treatment with air and ammonia under controlled conditions in two stages, both of which are at superatmospheric pressure and temperature. Mulcahy (80) stated that the economics of pickle liquor regeneration depend on (a) acid recovered, (b) cost of disposal, (c) increased efficiency from control of pickling, and (d) reduced heat input. Where the steel surface is large in comparison with weight, regeneration is now recognized as economical. He emphasizes the importance of efficient heat transfer in regeneration processes and describes a continuous process embodying this principle.

Pulp and Paper

It is interesting to note that during 1952 the bulk of the investigations concerning pulp and paper mill waste treatment was carried on by the industry itself with the cooperation of educational institutions. The effluents from the production of rag, rope, and jute specialty paper products and their response to physical, chemical, and biological treatment processes were thoroughly investigated. Previously only sparse and scattered data regarding these effluents were available. Rudolfs and Nemerow (116) divide the wastes from specialty mills in three parts; namely, blowdown liquor, wash and bleach waters, and machine overflow. The analysis of each fraction, together with its physical and chemical properties and significance in stream sanitation, was reported (117). Studies on the treatment of these wastes, both individually and combined, indicated that sedimentation was capable of reducing the suspended solids content substantially, and when supplemented with chemical coagulation could also effect good color reduction. Neither form of treatment could produce B.O.D. reductions in excess of 50 per cent and this removal level was seldom reached. Chemical requirements were high for any of the large variety of coagulants and combinations thereof employed. The sludges produced were thin and gelatinous (118).

Anaerobic digestion of rag, rope, and jute wastes indicated that B.O.D. reductions of about 75 per cent could be obtained at loadings of between 0.027 and 0.056 lb. of B.O.D. per cubic foot of digester capacity, employing a 6-day detention period at 35° C. The presence of sulfites in these wastes caused a lag in digestion (119)(83). Aerobic treatment of rope waste on a pilot trickling filter produced B.O.D. reductions seldom exceeding 50 per cent, despite preneutralization and the addition of nutrient salts (83). Difficulty in maintaining an effective slime on the stones was encountered despite careful control. From treatment by various methods of seeded aeration (83)(120) in the laboratory it appears that aeration with dispersed seed for a period of 24 hr. could produce B.O.D. reductions ranging from 78 to 96 per cent. These reductions could be produced in any of these wastes if the stronger fractions were sufficiently diluted, the treated material neutralized, and nutrient salts added.

Both laboratory and pilot-plant ex-

perimentation on chemical and aeration treatment of kraft mill waste continued throughout the year. Moggio (78) reviewed the entire background on this subject, including recent research on the lime-recarbonation process, which shows the most promise at present. Trials directed toward integrating this process with the kraft recovery system, which is effective in reducing the color of the waste, have been encouraging and progress has been made toward overcoming the former difficulties of control and lime-organic slurry thickening. Continuing development of the aeration process for treating kraft mill effluents was reported by Gehm (82). B.O.D. reductions of 90 per cent and color removal of 35 per cent have been obtained under controlled mill discharge conditions. A seed sludge of peculiar properties has been produced, among which are high buffering capacity, low oxygen demand, and nonputrescence on storage at high atmospheric temperatures.

Trobeck (134) describes the equipment employed for oxidation of kraft mill black liquor. He found that if sulfide in the liquor is completely oxidized, no sulfur is lost as hydrogen sulfide or mercaptans during concentration of the liquor to 50 or 60 per cent solids. Corrosion during the evaporating process was considerably less when using oxidized liquor. The condensate was not malodorous and could be discharged in the effluent. However, the oxidized liquor has a higher viscosity than unoxidized liquor below 140° F. Therefore, the author considers it advisable to empty lines containing oxidized liquor upon plant shutdown.

A study (148) of the kinetics of oxidation of sulfate black liquor showed that a series of simultaneous reactions occur which include a first-order reaction. This reaction is dominant during the first part of the process and is succeeded by slower reactions, which continue indefinitely. It is suggested that the oxidation of sodium sulfide takes place largely during this initial phase of the reaction. It was found that one volume of black liquor requires from 1 to 3 volumes of oxygen (5 to 15 volumes of air) for complete oxidation of sodium sulfide.

Operating results obtained from a demonstration plant for the treatment of de-inking wastes by sedimentation and activated sludge process were presented by Palladino (95). By sedimentation for 1.7 to 2.7 hr., 77 to 88 per cent suspended solids and 44 to 52 per cent B.O.D. removals were obtained. Sludge produced varied from 1.5 to 4 per cent of the waste flow. The sludge contained 8.5 to 12.5 per cent solids containing 32 to 53 per cent volatile matter. The removal of suspended solids by the secondary treatment varied from 85 to 94 per cent, of B.O.D. from 77 to 95 per cent. Considerable frothing took place in the aeration tank.

Experimental evaporation of neutral sulfite pulping liquors by submerged combustion (85) indicated that although the equipment cost of an installation would be considerably lower than for multiple-effect long-tube evaporators, operating cost would be higher even with low-priced natural gas as fuel. However, the process might prove of advantage if acetic acid recovery from such liquors is contemplated. Heat hydrolysis of sulfite waste liquor on a pilot-plant scale was accomplished by Nierman (84) with B.O.D. reductions as high as 60 per cent. It was concluded on the basis of the tests that this process would be difficult to translate into full-scale operation and offered no advantage over recovery processes, now in the advanced stages of development, which are capable of high B.O.D. reductions with attending high removal of dissolved solids and color.

Factors affecting anaerobic digestion of concentrated board mill white waters, obtained through the applica-

tion of highly-dosed paper machine water systems, were explored by Rudolfs and Amberg (111)(112)(113). At 30° C. relatively high B.O.D. reductions were obtained on digestion at 0.044 lb. of applied B.O.D. per cubic foot of capacity per day. Sodium sulfide in concentrations as high as 300 p.p.m. did not affect volatile acid decomposition or methane production. Removal of sulfides by aspiration with nitrogen or carbon dioxide, when concentrations exceeded this level, allowed digester loadings as high as 0.09 lb. of applied B.O.D. per cubic foot per day, yielding B.O.D. reductions of 68 per cent.

Waddell (138) points out that the OCO water system, as applied to a paper mill, eliminates discharge of polluted waters to a stream by conservation of water and fibers. The OCO water system includes reduction of waste volume, followed by recycling of high solids process water within the paper machine and filtration of the remaining low-solids water.

In order to study the decomposition of fiber deposits in rivers, a three-fold approach was suggested (4). The first step would consist of enumerating and identifying the microbial population of the flowing water and the deposits. The second would include the analysis of the soluble metabolic products diffusing from the deposits. Finally, the rate of decomposition of the fibrous material under natural conditions would be determined.

Ingmanson (67) derived an equation expressing the filtration resistance of compressible materials. He concluded that average specific filtration resistance is directly proportional to the product of the Kozeny constant and the square of the specific surface and is also related to the frictional pressure drop.

Plants for the neutralization of acid felt mill waste and for the treatment of asbestos paper mill waste were described by Ludwig and Ludwig (73) and Simpson, Duke, and Thompson (128), respectively. Wadleigh and Simons (139) presented design and operating data relative to the installation of Waco filters for the clarification of tissue mill waste.

Waste Treatment Charges

The question of how to establish equitable sewer rental and service charges has received some attention. Bankson (7) presented the method established by the Allegheny County Sanitary Authority for determining the proportionate share of both domestic and industrial users. The method apportions the charges between quality and quantity costs, and also between collection and plant treatment costs. For industrial wastes a special cost factor is proposed which will be applied to the normal sewage rates. Thus if B.O.D. and suspended solids are greater than those in the average sewage the surcharge factor will be greater than unity; if less, the factor will be less than unity.

Niles (90) in discussing a previous paper on the determination of fair sewage service charges for industrial wastes, illustrates how the methods proposed can also be applied to determining water rate charges.

Miscellaneous

The removal of color in paper deinking and cooking liquors was studied by Rudolfs and Hanlon (114) using spectrophotometric methods to determine the color characteristics of raw and treated wastes. They found that aerobic biological treatment increases the color intensity of rope, rag, and sulfite cooking liquors and board mill white water wastes, but decreases the color intensity of jute cooking liquor wastes. Anaerobic treatment of these wastes produced similar color changes.

One of the most significant papers of the year was presented by Green and Moses (49) on the destructive catalytic oxidation of aqueous waste ma-

terials. The method of oxidation consists of passing vaporized wastes and air at temperatures above 250° C. through catalyst beds of zinc, manganese, or copper chromites. The method has been worked out on laboratory and semi-plant scales, and oxygen consumed reductions of more than 99 per cent have been obtained.

Black (13) describes the procedures for sampling and measuring industrial wastes. He considers such sampling problems as the development of a sampling procedure and program, the use of automatic proportional sampling devices, and when to use manual sampling procedures. Methods of flow measurement and the proper use of metering devices are also discussed.

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WATER POLLUTION

Chemistry

Observations on the varying characteristics of a group of ponds and lakes into which yellow muddy waters flow led to scientific studies by the Oklahoma Agricultural and Mechanical College at Stillwater, Okla. (155). One of the important factors contributing to a clarification of the muddy (montmorillonite clay) waters was found to be increased acidity (CO_2 production) and possibly the coagulating effect of organic decomposition products. Coagulation of turbidity was confirmed in laboratory jar tests by adding dry or green grasses. An amount of green vegetation equal to three times the weight of suspended clay cleared impounded waters without critically depleting dissolved oxygen and without destruction of fish life. Taste and odor problems were not considered.

The prevalence of objectionable tastes and odors in water supplies of

the Missouri and Mississippi Rivers during the spring runoff was claimed (5) to be due to the natural decay of vegetable matter. Various oxidative processes and activated carbon treatment were applied with variable success.

Taste and odor problems from industrial wastes were reported by Welch (239). Periodically a mixture of acrylic-type chemicals and coal tar chemicals in the Delaware River water cause taste and odor problems at the Torresdale, Pa., water plant. The taste and odor was effectively controlled in laboratory treatment with 70 p.p.m. activated carbon to reduce the threshold odor from 20 to 5, followed by chlorination and dechlorination to a threshold value of 1.5. The acrylic odor was removed, but a slightly musty odor persisted. Prechlorination followed by activated carbon treatment was not as effective.

A chemical waste produced a strong taste in the river water of the London, England, area (15). One water plant, using sand filtration and carbon treatment, did not remove the taste, whereas another plant, using dual filtration and carbon, removed it completely.

Manson (136) reported that 4,000 gal. of kerosene was accidentally dumped into the Mascoma River when a trailer-truck overturned. The resulting intense taste and odor of the Lebanon, N. H., water supply was solved by the use of 70 p.p.m. of active carbon.

Two case histories were given by Muller (154) where considerable quantities of gasoline escaped into the ground. A gasoline odor was detected in wells to a maximum distance of about 3 km. Some persons can detect gasoline in water at a concentration of 1 p.p.m., and it becomes very noticeable at 10 p.p.m. In one case, the gasoline contained tetraethyl lead and the lead was present in a concentration of 0.5 p.p.m. Nitrates were reduced in well water containing gasoline. There was evidence of biological or catalytic oxidation of gasoline in soil.

Trace quantities of organic chemicals in surface waters were recovered for study by Middleton, Braus, and Ruehhoft (146). The chemicals were adsorbed on an active carbon filter. After drying the charged carbon, the chemicals were extracted with chloroform. Group separation techniques and infrared analysis were applied to the extract for a partial chemical identification. The neutral-type compounds were found to be principally responsible for taste and odor in water. Application of the technique to industrial waste studies was pointed out.

The contamination of surface waters by petroleum refinery wastes was reviewed by Villar (231), under the following headings: general characteristics of refinery wastes, harmful effects of contamination by these wastes, general requirements for treating liquid refinery wastes, and legal considerations in prevention of contamination.

Dietz *et al.* (54) studied the tumor-producing properties of petroleum fractions applied to the skin of mice. High-boiling (>700° F.) catalytically-cracked streams had high tumor potencies, as do similar fractions of steam-cracked tars. The carcinogenic properties were associated with the aromatic fractions. Precycle catalytic or thermal cracking was suggested as a way to eliminate the high-boiling fraction.

Wuhrman (245) discussed the purifying action of the soil on polluted water as it seeps into underground sand or gravel strata. The major purifying effect was claimed to be due to the adsorptive quality of humus and clay and the biological activity in the topsoil. The kind and type of topsoil were important considerations in protecting ground-water supplies. The pollution of ground water by large garbage and refuse dumps was discussed by Rossler (199). The water of a battery of wells 10 to 12 meters deep showed a marked increase in Cl, hardness, $KMnO_4$ con-

sumption, etc., beginning about 10 years after the establishment of a city refuse dump in the vicinity. The water of one well which was "upstream" (along the underground current) from the dump showed no such change in contents. There was no bacterial contamination of the affected wells. This was due to the filtering efficiency of the sand and gravel soil.

Van Haaren (228) reported that surface and ground waters were heavily polluted at a number of cemeteries by the decomposition products that leach out into the sandy soil.

Davids and Leiber (50) reported on ground-water contamination from the discharge of chromium-bearing industrial wastes into leaching pits. The concentration of chromium in some well waters was as high as 40 p.p.m. The chromium could be precipitated from the wastes by treatment with ferrous sulfate and lime to reduce the contamination to a level permitting safe discharge of the settled effluent in cesspools.

Extensive fish kills resulting from the drainage from gob-piles at a coal mine was reported by Gross (76). The drainage produced pH values in the receiving stream as low as 2.8. Leachings from the gob-piles were impounded in a 15,000,000 gal. reservoir. Satisfactory control was provided by discharging the impounded drainage in proportion to stream flow.

Bilharz (30) explained the pollution problems concerned with the dewatering of flooded zinc and lead mines located beneath shales high in pyrite and marcasite. The problem involved the discharge of a large volume of acid water into stream drainage, rivers, and impoundments. The mine water (pH 2.5) contained 6,500 p.p.m. Fe^{++}, 2,100 p.p.m. Zn^{++}, 25,000 p.p.m. SO_4^{--}, and 2,600 p.p.m. HCO_3^-, and was treated with CaO to pH > 4.5, aerated, and settled. Consumption of hydrated lime (200-mesh) was approximately 24 tons per 24 hr.

According to Todd (223), the Wheeling Creek dried up to only pools of stagnant water, which had offensive odors. The B.O.D. of the pond water was found to be as high as 35 p.p.m. Sodium nitrate (72 p.p.m.) was added to change the decomposition from anaerobic to aerobic, which effectively controlled the odor for 7 days.

Relatively unpolluted coastal waters around Norway usually contain less than 4 mg. nitrite per cubic meter, according to Braarud and Foyn (34). In the western branch of the inner fjord, furthest from the source of pollution by sewage, the nitrite content of the surface layers was low during summer, and higher (5 to 12 mg. per cubic meter) during autumn and winter. The deeper layers were poor in nitrites except in November and April. It was concluded that the high nitrite values obtained for surface samples are characteristic of the highly polluted waters in Oslo harbor throughout the year, and that the nitrite value would be useful as a criterion for assessing pollution in that area. In other circumstances the concentration of nitrite may be more closely related to the effects of biological activity than to direct pollution by sewage.

Langenberg *et al.* (113) considered the amounts of NaCl in Dutch water supplies in respect to their bearing on "saltless" diets. Results of determination of Cl and alkali (assumed to be Na) in the water supplies of the Dutch provinces, published by the State Department for Public Health for the periods 1938, 1943, and 1948–49, are tabulated and discussed.

In studying bactericidal effectiveness of chlorine treatment at high and low pH values, Markaryan (138) found that chlorine treatment does not affect carbohydrates, hippuric acid, and saturated fatty acids, whereas urea, amino acids, and creatinine forms nitrogen chloro derivatives.

In considering the industrial pollution of the Willamette River, Ore., Bol-

len (32) discussed the chemical and physiological needs of stream microorganisms as the agents of natural purification.

Cameron (37) modified the Gibson procedure for differentiating between animal and vegetable pollution by reducing the reaction time to 2 hr. and doubling the concentration of reagents. The Gibson method is the ratio of the NaOCl chlorine demand to the $KMnO_4$ oxygen consumed.

Bacteriology

During the year several investigators have reported the isolation of pathogenic bacteria from the water of polluted streams. Moore, Perry, and Chard (151) repeatedly recovered "paratyphoid bacilli" from a river flowing through a town of 10,000 inhabitants. Two paratyphoid B carriers and one typhoid carrier were discovered by systematic swabbing of sewers and modern culture techniques. These methods can be applied to the elucidation of unsolved enteric outbreaks and to the control of food-handling establishments.

Lendon and MacKenzie (123) isolated *Salmonella typhosa* from the water of Wallington River, Hants. The source of the organisms was traced to a carrier by use of Moore's swab technique. Samples of river water collected after a storm showed the presence of *Salmonella*. Further tests proved that the bacteria were being discharged from the storm overflow of a combined sewage system serving Purbrook.

S. typhosa and *S. paratyphosi* B were identified from the processed sewage effluent of Hanover, Germany, by Messerschmidt and Wedemeyer (145). At the point of discharge into the Line River, 21 of 45 effluent specimens were found to contain *Salmonella*. Of 25 specimens taken from the river up to 3 mi. below the outfall, 5 contained *Salmonella*. The sewage disposal plant consisted of a grill, a sand filter, and a sedimentation chamber, and had a total passage time of about 90 min.

A new *Salmonella* type was recovered from the water of Mendoza River by Leiguarda *et al.* (122). It was named *S. mendoza*. Accidental ingestion of the organism was followed by enteritis and diarrhea, which subsided spontaneously after one week.

Dunlop, Twedt, and Wang (56) described a quantitative method for the estimation of *Salmonella* in sewage-contaminated irrigation water. Several types of *Salmonella* were isolated from 8 of 11 irrigation water samples examined. The median value of all 11 samples was 0.9 *Salmonella* per 100 ml. of water.

Ross and Gillespie (198) reported an outbreak of gastro-enteritis affecting 160 of 1,250 factory employees and 28 persons in neighboring houses. Examination of the factory drinking water revealed the presence of more than 180 coliform organisms per 100 ml. of water. *Shigella sonnei* was isolated from 9 fecal specimens from persons attacked. *S. flexneri* and *S. typhimurium* were also found in one specimen each. The outbreak was caused by contaminated river water intermixing with the potable supply through a cross-connection. *S. sonnei* was later isolated from the river water.

An epidemic of acute infectious hepatitis affecting 22 persons occurred in an isolated rural area of Pennsylvania. Farquhar, Stokes, and Schrack (62) found the well water on the farm to be fecally contaminated from the nearby cesspool. Infection was apparently spread both by drinking water and by contact.

Seven specimens of sewage effluent from four tuberculosis hospitals yielded tubercle bacilli when examined by Kroger and Trettin (110). Tubercle bacilli in a ground suspension of infected guinea pig organs contained in a collodion bag and suspended in a stream remained viable as long as 48 days. The possibility of the water

from the stream receiving the sewage effluents infecting cattle was implied.

Because *Pseudomonas aeruginosa* has been isolated from many sources, Ringen and Drake (195) attempted to determine its normal habitat. A selective medium containing pyocyanin was used in studies to establish the incidence of this organism from various natural sources. *P. aeruginosa* was isolated consistently from sewage and from all parts of the sewage plant except the sludge. Feces from 11 per cent of the individuals examined contained the organism. Human feces, therefore, probably served as the inoculum for sewage and should be considered as the normal habitat.

Faneuf and Healy (61) reported that high counts of *E. coli* were observed in the water of Penacook Lake, the source of the Concord, N. H., water supply. The *E. coli* were derived from fecal matter on a picnic area near the screen house. Dosages of 10 p.p.m. chlorine were ineffective in disinfecting the distribution system, due to dissipation of chlorine by sediment in the mains. Fifty p.p.m. chlorine produced satisfactory samples. Emphasis was given the point that present methods of analysis do not reveal pollution until about 5 days after it has occurred.

The antigenic relationship of *S. dysenteriae* 2 (*S. ambigua*) and *E. coli* 0 group 112a,c were described by Ewing, Hucks, and Taylor (60). The 0 antigens of these two bacterial types are identical. Various interrelationships among enteric bacteria were discussed. These interrelationships directly contribute to the complexities of water examination and other laboratory tests related to enteric disease.

Sears and Brownlee (206) contributed further evidence in support of the thesis that the normal human harbors both resident and transient strains of *E. coli*. The resident group comprised one or two strains at any given time. The transient group was often absent and rarely consisted of more than three or four strains. In infants, resident strains may become well-established 10 days after birth. Both the transient and resident strains might change. However, the conditions under which strains were lost and new ones acquired could not be defined accurately.

In storage studies, the various members of the coliform group remained viable for long periods of time in both autoclaved and unautoclaved estuary waters as reported by Buck, Keefer, and Hatch (35). The bacterial cell densities exhibited cyclic changes, involving a decrease and a subsequent increase in numbers, at least twice in some experiments. If it was assumed that field conditions were in general similar to those in the laboratory, coliform organisms, once introduced into an estuary, would remain for a long time provided their number was not reduced by sedimentation, predatory protozoa, etc.

It was shown by Ketchum, Ayers, and Vaccaro (106) that the effects of dilution, bactericidal action of sea water, and predation accounted for more than 99 per cent of the decrease in coliform organisms in the Raritan River. The bactericidal action was the most important process followed by predation and dilution.

Joseph and Shay (102) determined the longevity of *E. coli* in acid mine waters. The rate of reduction on contact was rapid, but a small number of bacteria survived the 24-hr. testing period at pH 2.0. Factors active in self-purification studies were acidity, toxicity of compounds present, antagonistic action of microorganisms, food supply, and ingestion by protozoa. All waters of extreme acidities and of pollution with fecal material and mine wastes, which were examined, supported the growth of a few microorganisms. *E. coli* was among the bacteria which can sustain acid conditions in small numbers.

The Public Health Laboratory Service Water Sub-Committee (18) studied

the effect of storage on the coliform and *E. coli* counts of water samples. From 80 sampling points in England and Wales, 151 samples were collected. One portion of each sample was immediately tested for coliform organisms. Two other portions were stored 20 to 24 hr., one at room temperature (16° to 23° C.) and one at refrigerator temperature (2° to 5° C.) Coliform determinations were made by a 70-tube dilution method in which 10 tubes of MacConkey broth were inoculated with each of 7 two-fold diminishing volumes of sample. Significant increases in coliform organisms occurred in 23 (15 per cent) of the 151 samples stored at room temperature, and in 10 (7 per cent) of the samples stored in the refrigerator. Significant decreases of coliforms occurred in 29 (19 per cent) of the samples stored at room temperature and in 26 (17 per cent) of the refrigerated samples.

Goetz and Tsuneishi (73) described the chemical and physical nature of the molecular filter membrane, as well as several possible applications to water bacteriology. They listed several advantages of the molecular filter technique over present standard methods of bacterial analysis as: (a) nutrients may be removed or changed at any time during incubation; (b) different sections of the same filter deposit may be exposed to different nutrient media; (c) saves time and uses less equipment; (d) permits better and faster differentiation of bacteria; and (e) provides permanent records in the form of preserved filter discs.

Clark and Kabler (42) found that membrane filter procedures for the bacteriological examination of water gave promise of providing reductions in time, material, equipment, labor, and space required. Coliform determinations by the membrane filter procedure required approximately 18 hr. instead of the present 3 or 4 days. The same authors (104) also reported that by use of enrichment or inhibitory media, or both, with the filter, the growth of particular groups or species could be encouraged.

Goetz, Gilman, and Rawn (72) presented the results of tests using preimpregnated dehydrated nutrient pads with the membrane filter. Parallel tests for the coliform group on littoral waters (Pacific Ocean) using the membrane filter and "Standard Methods" serial dilution with lactose broth (M.P.N.) procedures showed comparable results.

Two independent incidents aboard Navy ships, in which fecal organisms failed to produce visible colonies on S.S. agar after 18- to 24-hr. incubation at 37° C. were recorded by Wharton (240). This "no growth" phenomenon showed a definite tendency toward repetition from the same individual. It rarely occurred in cultures from those persons having had demonstrable shigellosis, whereas it tended to occur frequently in those persons in the same environment who apparently escaped shigellosis. The author suggested the possibility of bacteriophage or nonpathogenic organisms commonly found in the bowel as responsible by producing antibiotics.

Weaver and Boiter (237) isolated from waters of Fayette County (Ky.) wells, 15 strains of *B. subtilis* and 13 strains of *B. cereus* that were antagonistic for *E. coli*. Almost all of the strains of *B. subtilis* produced antibiotic substances active against *S. flexneri, S. typhosa, S. paratyphi,* and *Micrococcus pyogenes var. aureus.* These results indicate that *Bacillus spp.* may affect the longevity of enteric organisms in surface waters.

The effects of bacteriophage on the survival of *Enterobacteriacea* in polluted waters from various sources were studied by Guelin and Gazdawa-Le Bris (79). They found that the bacterial count decreased progressively for the first few days and then dropped abruptly on the seventh day. The sharp decrease was accompanied by a rapid clearing of the medium. This

clearing phenomenon was not observed in autoclaved waters. Salmonella phage I from large isolated bodies of water was specific, while the phage I from small bodies of water was multivalent and attacked the coli-typhoid-dysentery group of organisms.

Bacteriophage for *Clostridium welchii* has been isolated by Guelin (78) from polluted water in quantities proportional to the degree of pollution. The numbers of *Cl. welchii*, and consequently of the bacteriophage, are often lower than the numbers of *E. coli* present. The bacteriophage can reduce the bacterial population by lytic action and under natural conditions might assist in the purification of polluted water.

When studying silver compounds as water disinfectants, Polster and Brazdova (180) observed best results with a complex Na-Ag chloride, called Sag I, which decomposed in water to give colloidal silver chloride.

Riehl, Weiser, and Rheins (194) reported that *E. coli*, *S. typhosa*, and *S. montivideo* do not survive prolonged exposures in waters of high pH maintained by addition of excess lime. Most of the test organisms were destroyed by exposure of slightly more than 4 hr. at a pH range of 11.0 to 11.5 and at a temperature of 15° C. Freshly isolated strains were more resistant than the same species propagated several months on culture media.

Elemental iodine is an efficient disinfectant of water. The amounts required to kill 13 strains of test organisms at varying conditions of pH and temperature were determined by Chambers *et al.* (41). The bactericidal action of iodine resembled that of chlorine in that greater activity accompanied higher temperatures and lower activity was exhibited at higher pH ranges. *S. sonnei* and *S. flexneri* I appeared to be somewhat more resistant than the *E. coli* strains studied.

Simulated and authentic nitrate-bearing well waters were prepared by Tubiash (227) at levels ranging from 0 to 240 p.p.m. nitrate-nitrogen. These waters were seeded with the equivalent of minimal and relatively heavy pollution of *E. coli*, *A. cloacae*, *A. aerogenes*, and a mixture of the three organisms. Markedly ambiguous reductions in M.P.N. were obtained with heavily-seeded waters at levels of 100 p.p.m. nitrate-nitrogen and over. Equivocally negative M.P.N. values were obtained with the lightly seeded waters at levels of 100 p.p.m. nitrate-nitrogen and over. Bacteriologically nonpotable nitrate-bearing waters may erroneously appear potable when subjected to the "Standard Methods" presumptive test, because of the inhibitory effect of the nitrates on the production of visible gas by members of the coliform group.

Kichatova (107) has recommended the use of rosolic acid medium for the determination of fecal contamination in water. When used in conjunction with a yeast lysate growth stimulant, useful results were obtained in 12 hr.

Findlay (64) described a growth of *Armillaria mellea* 10 ft. long in the Carlesmoor water tunnel leading out of Roundhill reservoir, England. Another growth 30 ft. long was found in the same tunnel about 7 years earlier. Nutrients for the growth of the fungus were probably derived from the clean water.

Biology

Practical biological techniques can distinguish degrees of pollution, and aquatic organisms can indicate a wide range of stream conditions from healthy to grossly polluted (88). Mills (148) suggests that studies of fish life are of interest and value in evaluating the biological effects of stream pollutants.

A valuable textbook for those interested in stream pollution is that of Liebmann (124). The author notes the techniques required for the examination and evaluation of biological con-

ditions in water supplies, fishing waters, sewage, and waste waters. The section on methods of biological examination includes description of sampling methods useful in various situations, and chemical and bacteriological methods of value to the pollution biologist. Other sections deal with organisms associated with different degrees of organic pollution and with some toxic wastes. Greenburgh (75) suggests procedures for sampling river water and observations to be made when fish kills have occurred.

Mackenthun (131) and Newcombe (159) review the effects of pollutants on the ecology and animal life in streams. The zones of an unpolluted river are classified by Huet (94) according to the predominant fish species. The effects of pollution on the streams are discussed and the typical plants and animals of the various zones of a sewage-polluted stream are listed. The chief effect of toxic wastes is a reduction in the numbers and kinds of animals. Mann (135) divides wastes harmful to aquatic life into three main types, those from the chemical industries (coal mines, cement works, soda factories); those containing toxicants (metallic wastes and coking wastes); and the organic wastes.

Stopford (216) found that a discharge of sewage into an estuary may have a strong local effect on aquatic organisms. The normal fauna was, however, not affected adversely during the hot summers. Thomas (220) reported that the Turlesee, Switzerland, which before pollution by the effluent of a cheese plant and by agricultural fertilizers contained adequate oxygen at all depths, now displays a marked deoxygenation of its deeper water. Adequate oxygen is limited to the upper strata, plankton is restricted to a few species, and the lake water is now unfit as a source of water supply. Similarly, Lake Zurich (219) has been made eutrophic because of domestic wastes. Fish populations have been damaged and the use of the lake as a water supply has been limited. On the other hand, Gross (17) showed that the controlled fertilization of a sea-loch has resulted in a greatly increased growth rate of fish because of the stimulus to plankton organisms.

Several valuable papers on the methods and apparatus used to conduct bio-assays of toxic substances to fish have appeared. Tomiyama and Inouye (224) describe an apparatus which maintains a constant supply of the pollutant and of various acids and alkalies to maintain a fixed pH. Herbert (86) discusses the objectives of bio-assay procedures with fish, the effects of the numbers of fish in fixed-volume tests, and the advantages of constant-flow systems, and outlines an apparatus which can test 50 fish at one time. Also mentioned are the effects of low D.O. and the chemistry of the diluting water on the toxicity of substances. This comprehensive paper also mentions methods for the interpretation of results, and discusses variations in resistance among fish and the effects of acclimatization of the fish on the results of bio-assay procedures. Wuhrmann (246) also considers various factors that influence the results of bio-assays with fish. De Savelle and Hubault (52) describe bio-assay techniques used in France and give toxicity data for chlorine, chlorides, ammonia, and alkalies. Vivier (233) recommends supplementing with laboratory bio-assays, tests for toxicity made by suspending caged fish in streams suspected of being polluted.

Several summaries of the published data on the toxicity of industrial wastes and their components have been made available. McKee and Gilman (142) compiled from the literature data on the toxicity of hundreds of substances to fish, aquatic life, livestock, shellfish, and wildlife. LeClere and Devlaminck (120) list the toxicity to fish in both distilled and hard water of 33 inorganic and organic substances. Mack-

enthun (130) tabulated the toxicity to fish and invertebrates of 217 inorganic and organic substances, industrial wastes, and other substances discharged into streams.

Kubota (111) found that fish eggs could be hatched at a pH range of 3.8 to 10, but that the optimum range was between pH 6 and 7.2. Malformed young were hatched in strongly acid or alkaline waters. Jones (101) noted that at low temperatures (13° C.), sticklebacks could not detect water of low D.O. and distress symptoms were slow to appear. At 20° C., distress is so prompt that fish would not swim into water with a D.O. of 2.0 p.p.m. Minnows and trout were found to react similarly. Privolnev (182) observed that young Atlantic salmon fingerlings of different ages varied in their tolerance to waters of low D.O. Forty-day-old fish are restricted to waters having over 3.5 p.p.m., whereas 110-day-old fish were more tolerant and could survive in waters with 1.0 p.p.m. and higher. Lassleber (116) noted that carp raised in ponds in which the oxygen content was 150 per cent of saturation or higher had a high frequency of maxillary disease and dropsy. Fish were healthy in ponds in which the oxygen content reached 125 to 150 per cent saturation. The author believes that an abnormally high D.O. is dangerous to the health of fish. Egusa (59) investigated the diseases in fish caused by a supersaturation of nitrogen in an artesian water supply.

Scheuring and Stetter (202) found that carp, perch, and trout were killed in 1 to 5 p.p.m. chlorine within 15 to 72 hr. The toxicity of chlorine to tadpoles, crustacea, snails, leeches, and some plankton organisms was also determined. Corti and Weber (46) studied the activity of trout in an ammonia solution. An apparatus called a "tarachograph" was developed to record electrically the reactions of fish in toxic solutions. Cremer (47) and Eden, *et al.* (58) determined the toxicity to fish of H_2O_2, hydrazine, and methyl alcohol, which are wastes resulting from the testing of rocket engines. H_2O_2 was toxic to fingerling rainbow trout at 40 p.p.m., 0.7 p.p.m. hydrazine hydrate caused a loss of equilibrium in less than 24 hr., and up to 8,100 p.p.m. methyl alcohol was harmless in 24 hr. Rainbow trout were unaffected by 10 p.p.m. of formaldehyde in three days, but 50 p.p.m. killed within one to three days. 500 p.p.m. of ammonium sulfate was toxic to fish, and fish food organisms were killed by lower concentrations (222). 2,500 p.p.m. of ammonium thiocyanate was lethal. Wuhrmann, Zehender, and Woker (247) emphasize that the toxicity to fish of solutions of ammonium salts depends mainly on the amount of nonionic free ammonia, which can be determined from the concentration of the solution and the pH. Woker (244) found that the toxicity to fish of various concentrations of ammonia was not dependent upon the water temperature. In experiments, the D.O. was maintained at 9 to 10 p.p.m. and the temperatures of the various test solutions were 10°, 14°, 17°, and 25° C. The same mortalities were observed at all temperatures. Wuhrmann and Woker (248) found that the threshold of toxicity to minnows was around 1.0 to 1.2 p.p.m. NH_3; trout fry were sensitive to 0.3 to 0.4 p.p.m. NaCN at 0.33 to 0.35 p.p.m. killed minnows in 2.5 hr. Solutions containing mixtures of NH_3 and CN are more toxic than either solution alone. The authors believe that these toxicants penetrate through the gill membranes. Czensny (48) found that the HCN in metalworking wastes is toxic to trout in concentrations of 0.1 to 0.15 p.p.m. HCN. Instances of fish kills due to cyanides in industrial wastes were reported from Germany and the United States. (3) (39) (203)

LeClerc and Devlaminck reported on the toxicity to fish of the component chemicals of wastes from explosive fac-

tories (119) and from tanneries (117). The minimum lethal dose to fish that had been immersed for 6 hr. in distilled- and tap-water solutions of the various waste components was determined. These include mono- and dinitrophenol; TNT; dinitrocresol; mono- and dinitrobenzene; hydrochloric, boric, tannic, and lactic acids; sodium bisulphite; sodium borate; sodium metabisulphite; ammonium chloride; sodium sulfide; sodium sulfate; ammonium sulfate, and chromium sulfate.

Beeckmans and Beaujean (28) also reported on the toxic effects of tannery wastes to fish. After pollution by cotton mill wastes, Dendy (51) was able to find only 3.4 lb. of fish per acre in Sougahatchee Creek, whereas prior to pollution this creek yielded 41 lb. per acre.

Siyazuki (208) observed the effects of effluents from a fermentation plant, a brewery, and a pulp mill upon a landlocked bay. Analyses were made of the effluents, the bay water, and muds. Fish kills observed were attributed to the organic wastes from the plants. Redfield and Walford (190) studied the effects on plankton and fish of the disposal at sea of 4,000 tons per day of an acid waste containing ferrous sulfate and sulfuric acid. Although zooplankton in the discharge area were temporarily affected, the organisms recovered when the waste was diluted and no biological harm was indicated.

Scheuring (201) found that trout fry and insect larvae survived several days in a 1.5 to 2 per cent solution of sodium sulfate, but protozoa survived for 28 days. Potamogeton was affected by a 0.5 per cent solution, while other plants were affected by 1 per cent solutions.

Tomiyama and Yamagawa (225) determined in a constant-flow apparatus that sodium sulfide was more toxic at low pH values; 0.55 p.p.m. was lethal at pH 5.2, whereas at pH of 8.2, 8.0 p.p.m. was lethal.

Mackereth and Smyly (134) report that the stoneloach, *Nemacheilus*, died in water containing 0.2 p.p.m. or more of Cu. Paul (174), in a discussion of the biological effects of water pollution in California, notes that certain resident trout populations have become acclimated to copper concentrations that kill introduced hatchery-raised fish. Studies also indicate that some common household detergents may be toxic at levels of 10 to 20 p.p.m. Mackenthun (132) and Mackenthun and Cooley (133) demonstrated that the copper content of mud at the bottom of heavily-treated Lake Monona, Wis., is far below that which will kill bottom-dwelling organisms. 9,000 p.p.m. Cu in bottom muds was found to be toxic to bottom-dwelling fauna.

The toxicity of water in contact with zinc-coated metals is markedly higher in soft than in hard waters (179). Severe losses of trout eggs and fry in an Australian hatchery were found by Affleck (2) to be due to zinc (0.04 p.p.m.) dissolved by slightly acid water (pH 6.0 to 6.8) from galvanized-iron pipes. Laroze (115) contends that the mortalities of fish in trout ponds were due to small amounts of Fe. Microscopic examination of the gills indicates the penetration of a semi-colloidal basic iron salt into the gill tissues.

Kozima and Tomiyama (109) analyzed waters in trout hatcheries for many ions in an effort to correlate water chemistry and mortality of young rainbow trout. It was found that the mortalities are directly proportional to silicate content and inversely proportional to calcium content of the hatchery waters. By using radioactive calcium Lovelace and Podoliak (126) showed that small rainbow trout absorb calcium through the gills from the surrounding water. The calcium is then distributed through the body by the blood stream. Kaemmerer and Erichsen (103) found that nickel was more toxic to fish than Fe and Mn. Mn seemed to be slightly antagonistic toward Ni. Effluents from lead mines

were not only toxic to fish, but the precipitates also cover spawning grounds and destroy fish food organisms.

Specht (213) tested the toxicity of chemicals used in the flotation processes of the phosphate industry and found that tall oil was the only agent liable to be toxic to fish.

Gillette, Miller, and Redman (70) tested 51 organic compounds, mostly alcohols and amines, to determine their toxicity to fish. The most toxic compounds were simple alkyl amines, sodium hydrosulfide, phenol, ammonium hydroxide, and 1,3,dibutylthiourea. The toxicity of alkylamines and ammonium hydroxide was reduced by adjusting the pH of the test water near neutrality.

Fish kept in sublethal concentrations of kraft pulping wastes did not develop any observable pathology of the gill and liver tissues (229). Haydu, Amberg, and Dimick (84) studied the toxicity of kraft pulping wastes and their components to typical anadromous salmonid species of the Pacific Northwest. Tests were conducted in aquaria and in an artificial stream designed to simulate a natural stream environment. Aquatic insects were also tested.

Lindenberg and Gary-Bobo (125) determined that the threshold concentrations of various aliphatic alcohols as determined by the narcosis of fish was not a function of the length of the carbon chain of the alcohols, but varied according to the pharmacodynamic action of the various compounds. The narcotizing concentrations of the various alcohols were not the same in different fish species. Dilutions at the threshold of physiological action and the concentration at the abolition of reflexes in fishes for several hydrocarbons and their polar derivatives were also determined (68). It appears that water solubility of a compound affects the value of the threshold activity only when the solubility is above a minimum value.

Maramorosch (137) found that fish were killed when placed in water containing cellulose acetate sheets. The plasticizer, diethyl phthalate, which diffused into the water was the toxic agent. Raffy (188) found that certain fish placed in 0.25 to 1.5 per cent alcohol showed an increased oxygen consumption, whereas other species showed a decrease. Sollman (209) found that hydroquinone in water is 100 times more toxic to goldfish than phenol. Tertiary butyl catechol was also highly toxic. These substances act by inhibiting many of the autocatalytic processes of fish. It was found (40) that fish subjected to 0.1 p.p.m. or more of S-guaiacazulene died of anoxemia within 6 hr.

Bogenrieder (31) found that intravascular blood coagulation occurred in fish poisoned by phenol or nitrobenzene. Coagulation occurred in one-half of the fish killed by dinitro-orthocresol. No coagulation was found after carbolineum poisoning.

Aust (21) described the danger to fish of sprays containing carbolineum, mineral oils, and insecticides. Fish kills have been caused by washing spraying equipment in streams. The effects of arsenic and arsenic compounds, pyrethrum, derris, dinitro-orthocresol, DDT, and the newer insecticides were also discussed. Aust (22) states that DDT at a concentration of 19 p.p.m. is toxic to fish. An indirect action is the destruction of natural fish food by the insecticides. Bandt (24) found that the insecticide hexachlorohexane is a nerve poison, but acts so very slowly on fish that it is probably not dangerous. It is, however, very toxic to fish food organisms. Ginsberg (71) determined that dieldrin was twice as toxic to fish as aldrin; 0.25 p.p.m. of aldrin and 0.125 p.p.m. dieldrin killed all the fish tested; 0.25 p.p.m. DDT killed all fish tested. Fish kills have been reported in Oklahoma

(235), where aldrin and toxaphene have been used as insecticides. In 10 hr., 0.5 p.p.m. aldrin kills many fish species. The toxicity of aldrin persists in water from 4 to 5 days.

Huet (93) reports that substances toxic to fish are found in the humus formed in spruce forests. This ultimately results in a depletion of aquatic life and the disappearance of fish in streams draining spruce forests. LeClerc and Devlaminck (118) investigated the toxicity to fish of the resins and terpenes from conifers. Most toxic resins were those of larches and least toxic from cedars of Lebanon, Corsica pine, and Thuja. Bandt (25) found the extracts of needles, twigs, and fruit of arborvitae and juniper to be toxic to fish and those of Taxus not toxic.

Duuren and Groenewoud (57) made a chemical investigation of the tuber of *Neurotanenia edulis*, which is poisonous to fish. They extracted and determined six organic compounds from the tuber. The toxicities of these compounds were determined; two of the six were definitely toxic and one of these exhibited physiological action similar to rotenone.

Petard (176) lists some plants containing saponins, rotenones, and other substances toxic to fish.

Mortalities of animals attributed to toxic algae have been reported from various localities in North and South America, Africa, and Australia. Olson (172)(173) suggests that algal toxins might be the cause of unexplained dysentery epidemics in the Ohio and Potomac River basins and might be correlated with the condition known as Haff's disease in Europe. Scott's (205) review emphasizes that fresh algae are more toxic than decomposed algae and that frozen and dried algae are most toxic. The chemical nature of the toxin is unknown, but it is secreted by the algae in the surrounding water, killing animals that drink the water. On the other hand, McLeod and Bondar (144), while investigating the death of domestic animals caused by drinking water that was blooming with *Aphanizomenon flos-aquae*, killed mice and rats by allowing them to drink a suspension of lake water and algae. The lake water was non-lethal after the algae had been removed.

Ingram (95)(96)(97) prepared a series of selected bibliographies of value to those interested in the biological problems of water supply and water pollution. Titles listed deal with water treatment, water pollution, plankton nuisances, algal control, and the identification of plants and animals found in polluted streams.

Ingram and Palmer (98) present in detail methods of collecting, counting, identifying, and recording plankton with the intention of enabling water plant operators to predict and prevent plankton blooms. Moore (152) attempts to obtain, from a statistical examination of a large number of data from several sources, some evidence of the magnitude of errors present in plankton counts and from this information to estimate the reliability of the counting procedures used to enumerate microscopic organisms in water.

Pearsall (175) emphasizes that a knowledge of aquatic biology is of importance to those concerned with water supplies. For example, vigorous algal growth may reduce the water hardness as much as a third. Algae in improperly designed reservoirs can create operational difficulties. Wohlschlag and Hasler (243) studied the populations of blue-green algae in Lake Mendota to determine conditions leading to algal blooms. Algal density was determined by measuring chlorophyll concentrations. Verduin (230) found that photosynthesis by phytoplankton in Lake Erie can be measured by using the changes in pH as an index of the removal of CO_2. A high correlation was found between the volume of algae and photosynthesis rate; and it is suggested that the volume of algae be taken as an index of productivity.

Phinney (178) outlines some of the fundamental studies necessary for an elucidation of the role algae play in the ecology of polluted and unpolluted streams. Phytoplankton use soluble carbohydrates, fat-soluble organic compounds, salts of organic acids, and nitrogenous organic compounds. Sorenson (210) found the alga *Hydrodictyon*, which is normally rare in Sweden, to be abundant in one river polluted by sewage and trade waste waters. Analysis of the water from various points of the river are given. The alga occurs in that stretch of the river which has recovered from the effects of pollution. The toxicants and sludge in the wastes of Paris change the character of the plankton in the River Seine (121). Other variations in the plankton production can be correlated with variations in the depth of water, light penetration, and water temperatures.

The addition of salts containing nitrogen and phosphates into waters containing phytoplankton leads to an increased D.O. (27). The addition of superphosphate and ammonium nitrate into reservoirs and lakes gives similar improvement in photosynthetic activity, which lasts for several days after the addition. Sawyer (200) points out that the increasing use of detergents, many of which have high phosphate contents, may increase algae problems in water. The average content of phosphate in sewage has doubled in the past 10 years.

Topinska-Luchter (226) investigated the micro-flora populations in waters with various amounts of hydrogen sulfide. In waters containing 20 to 50 p.p.m. hydrogen sulfide an abundance of sulfur bacteria of various types, as well as blue-green algae, were present. Waters containing more than 50 p.p.m. hydrogen sulfide contained only motile red sulfur bacteria.

Although the city of Lucerne, Switzerland, had stopped polluting the water of Red Lake for about 12 years, the oxygen content in the lake was still critical (149). There was only 0.16 p.p.m. D.O. at 5 m. and none at 15 m. The plankton species consisted chiefly of *Oscillatoria* and *Leptothrix*. Jaag (100) found that the heavy contamination of Swiss lakes has reduced their oxygen content. FeS has deposited, *Oscillatoria rubescens* has become predominant, and the fish populations have suffered.

The radioactivity of the plankton in the Columbia River below the Hanford, Wash., works was considered to be insignificant. The radioactivity of the plankton carried by the river past Hanford during July was 0.6 curies per day (44).

Surfaces coated with a newly patented rosin amine algicide (33) kills algae and inhibits regrowth. Fitzgerald *et al.* (65) screened 300 organic compounds for toxicity to bloom-producing blue-green algae. Several quinone-type compounds are toxic in concentrations of less than 1 p.p.m. The chemical 2,3,dichloronaphthoquinone is lethal in concentrations as low as 2 μg. per liter. This compound is selectively toxic to bloom-producing algae and is nontoxic to most green algae and higher plants. In short term tests, it was found to be nontoxic to fish and other aquatic animals in concentrations used for algae control.

Flentje (66) discusses the use of phytocides in water weed and algae control. Snow and Iantosca (211) treated a fishy taste in reservoir water caused by *Uroglenopsis*. They chopped holes in the ice and treated with copper sulfate to a concentration of 0.06 to 0.90 p.p.m. Williams *et al.* (242) found that 15 p.p.m. of various quaternary ammonium compounds controlled the growth of algae. 5 p.p.m. Arquad S is effective against *Oscillatoria*. Bervoets (29) tested the toxicity of hexacyclohexane to plankton. It was found to be far more effective in running water.

In 1908 and 1909 Kolkwitz and

Marsonn, in their classic work, classified aquatic organisms according to the condition of the water of which they were typical. In a new revision, Kolkwitz (108) has further developed this classification and lists plant and animal saprobes with descriptions of species and the conditions of which they are typical.

Ferramola (63) found that the earthy odor of Plata River water is caused by the growth of *Streptomyces* in river bottom sand exposed by drying southern winds. The odors are absorbed by the returning water. The dryness of the air, aeration of the soil, presence of vegetable wastes and other carbohydrates, all favor the development of the *Streptomyces*. Deuticke *et al.* (53) review the causes of the tastes and odors produced by algae. They found that the ether-soluble lipoids contained in three different algae vary in composition. The amounts of essential oils obtainable by steam distillation also vary widely.

Harvey (82) studied the distribution of fungi in the various polluted zones in the watersheds of the Great and Little Miami River valleys in Ohio. Some species were always absent from heavily polluted waters, others were found in moderately polluted areas. Only *Aphanomyces* showed an affinity for polluted water.

Wastes from buna works contain organic materials which stimulate heavy fungus growths downstream from the plant discharge point. Studies are being made to determine these nutritive substances preliminary to treatment at the plant (189).

Gaufin and Tarzwell (69) made intensive studies of the bottom invertebrate fauna found in the various pollutional zones of a Midwest stream contaminated by domestic sewage. The numbers and kinds of bottom organisms were correlated with the pollutional zone, season, and physical and chemical conditions in the stream.

Mohr (150) discussed protozoa as indicators of pollution, but feels that protozoa along with other animals are better indicators of pollution than protozoa alone. Protozoa in polluted marine waters are similar to species found in polluted fresh water. They are sensitive to toxicants and are reduced and eliminated in their presence. Protozoa are, therefore, suggested as bio-assay organisms in the detection of toxic wastes.

Vinogradov (232) determined that the small consumption of oxygen by zooplankton cannot affect significantly the oxygen content of the water in reservoirs where photosynthesis and replacement from the atmosphere can operate. In the deeper layers, an oxygen deficiency can be caused by the metabolic demands of these animals. The oxygen consumption for some plankton crustaceans was determined. Carillo *et al.* (38) reported that microcrustacea, mostly *Cyclops* and *Diaptomus*, were clogging the filters of the Buenos Aires waterworks. 20 p.p.m. of copper sulfate killed all the crustaceans within 24 hr. Treatment of the raw water with chlorine sufficient to leave a 1.5-p.p.m. residual reduced the number of crustacea after coagulation by 72 to 81 per cent. Coagulation alone reduced the numbers of crustacea by 22 to 37 per cent. Zischkale (250) established the tolerance of several aquatic crustaceans, mollusks, and insects to rotenone, 2,4-D, 2,4,4-T, and sodium arsenite.

Negoro (158) surveyed the physical, chemical, and biological characteristics of the acid lakes and streams of volcanic origin in Japan. pH of the lakes varies from 3.5 to 5 and of springs from 1.2 to 3.2. The waters are highly mineralized. Sulfur oxidizing bacteria are abundant, algae are scarce.

Gray (74) studied the association between ciliate protozoa and algae in a chalk stream. Although there was no close correlation between total bacterial numbers and total numbers of ciliates present, the highest bacterial numbers

occurred where diatom-eating ciliates were dominant. Bacteria-eating ciliates were correlated with the presence of Gram-negative rods in the bacterial flora, whereas Gram-positive rods were correlated with the presence of diatom-eating ciliates.

Kuntz and Wells (112) demonstrated the toxicity of dinitro-o-cyclophenyl and its dicyclohexylamine salt to mollusks. These were toxic at 3 to 5 p.p.m. and were not adversely affected in their action by water of high organic content. These are best used in conjunction with copper sulfate in schistosome vector control.

B.O.D. and Oxygen Sag

Widespread realization that photosynthesis frequently is the most important factor in determining oxygen sags is the most significant development of the year in this field. Stone and Abbott (215) presented evidence of overall positive contributions of oxygen as the result of photosynthetic activities, showing that oxygen produced by illuminated green microorganisms would not be equaled by the respiration of those organisms when in the dark. Abbott (1) presented test procedures designed to make allowances for photosynthesis in estimating stream loading by effluents. He concluded that conditions are so complex in rivers that no test can be devised to accurately reproduce them, and stated further "there is a limit to the realism which can be imparted to modifications of the B.O.D. test." Ludwig and Oswald (129) studied *Euglena* in sewage-polluted streams and ponds. In streams under favorable nutritive conditions (highly polluted) the organisms are vigorous and produce an excess of oxygen. Downstream, in the zones of recovery, the *Euglena* change morphologically and physiologically, use more oxygen than they produce, and create an oxygen demand. *Euglena* serve as a source of food to zooplankton and fish. Gaufin and Tarzwell (69) presented data on the systematic diurnal variation of D.O. along a small creek with a single important source of pollution. From data which embraced all seasons (218), it was apparent that the diurnal variation of D.O. was of such magnitude that it could not be reconciled to the usual sag curve concept.

Snow (212) studied the effect of partial chlorination of sewages on the ultimate B.O.D., on oxidation constants, and on the initial rate of oxygen consumption. Iz'yurova (99) pointed out the importance of nitrogen, potassium, and phosphorous in relation to biological oxidation of petroleum products. Natermann (157) suggested certain modifications of the method of Fair and Kehr (Imhoff, K., "Tachenbuch der Stadtenwasserung." 14th ed.; 1951) to take into account river conditions, such as weirs, not contemplated in the original method.

Stream Surveys and Studies

A pollution survey of the Willapa River estuary, supervised by the Washington State Pollution Control Commission, to determine the acceptability of a proposed kraft-type pulp mill site was reported by Sylvester (217). Calculations based on minimum river flow, estuary volumes and velocities, mixing (as indicated by chloride concentrations), dissolved oxygen, and toxic wastes concentrations, indicate that the location of the plant more than 10 mi. from the bay entrance will result in serious dissolved oxygen depletion in the estuary. Constant-rate discharge of waste water is recommended, rather than discharge at ebb tide only, to secure better mixing, as the wastes may remain in the estuary up to 38 days before discharge into a larger volume of dilution water.

McDill (140) described the survey of the Maumee River conducted by Ohio and Indiana personnel working jointly toward the abatement and control of pollution in that basin. The results indicate that a 65 per cent reduction in

the present pollution load is required at the critical flow condition, which has been established as the minimum seven-consecutive-days average flow which will probably occur in 20 per cent of the years. The major water use in the basin is for public water supplies.

The Ohio River Valley Water Sanitation Commission (170) published a report of a survey on the Wabash River between Keenesburg, Ill., and Terre Haute, Ind. The survey consisted of two sections: (a) collecting and analyzing hydrologic, waste discharge, and water quality data; and (b) evaluating this information in terms of regulatory requirements. Youngquist (249) described the purpose and organization of the Lake Erie pollution survey being conducted by the Ohio Department of Natural Resources. Preliminary investigations have included collection of data on the quality of sediment discharged to the lake by rivers, and bacterial and chemical analyses of tributary rivers. On the basis of information thus far obtained, an estimate was made of the extent and nature of pollution in streams entering Lake Erie and of its effect on the use of the lake waters for industrial and other purposes. The New York State Department of Health (160) (161) (162) (163) (164) (165) issued a number of reports on surveys made to obtain data necessary to clarify the waters in the various basins under provision VI of the Public Health Law. Generally a summary of past surveys, water index system, hydrology, land and water uses, present defilement, results of survey, and the recommended classification are included in the reports.

A detailed method for calculating the oxygen resources of San Diego Bay was described by Nusbaum and Miller (169). They discuss reaeration from the atmosphere, oxygen produced by chlorophyll-bearing phytoplankton, and oxygen supplied by tidal exchange. Oxygen demand loadings are presented. Data and supporting material obtained during a survey of San Diego Bay in 1951–52 by the California Department of Health and California Department of Fish and Game, along with long-range water use objectives, are included.

Cabejszek and Wlodek (36) reported on a survey of the Kamienna River in Poland. Physical, chemical, bacteriological, and biological analyses of river water show that the upper reaches of the river are not polluted, while the waters below the confluence of the Kamienna and Szewnianka Rivers show pollution. The Kamienna River is very heavily polluted from unsatisfactorily treated wastes from a sugar factory. Stangenberg (214) stated that, except at its source, most of the Bystrzycy River is like an open sewer. For improvement of the river the author includes recommendations to activate all available treatment plants, to design and construct new ones where needed, and to require all plants to submit reports of operation.

The effect of industrial wastes discharge on the Hooghly River in and around Calcutta was discussed by Seth and Bhaskaran (207). Their survey indicated that paper mill wastes caused no pollution beyond 50 ft. from the outfall and that textile wastes caused no pollution zones. The river supplies adequate dilution for sewage and industrial wastes.

Abatement and Control

General interest in the problem of abatement and control of water pollution has increased during the past year. Schwob and Dworsky (204) review the program in water pollution control in recent years and state that the Water Pollution Control Act of 1948 authorizes the Public Health Service to initiate the development of programs for water pollution abatement. Pirnie (6) stresses that any development in waste treatment must be worth what it costs. National water resources policy relating to stream pollution is discussed by

Howson (92). Present pollution controls are believed adequate with control invested in the lowest level of government having jurisdiction over the stream. Wieters (241) reviews the cooperative activities of the state and federal governments under the Water Pollution Control Act of 1948. Schwob (12) states that efforts to abate pollution will proceed from the "fact finding" to the "practical" stage during 1952. He mentions that there are 22,000 significant sources of pollution listed for the nation with 11,800 municipal and 10,400 industrial sources. Murdock (156) discusses industrial waste pollution and its relation to Southern watercourses. He states that the Southern Association of Science and Industry is taking steps to assure that Southern streams are kept sufficiently clean for the needs of industry, agriculture, and the public.

A review of the water pollution control problem from the point of view of the refinery operator is presented by Nord (168). He discusses the nature of pollution, types of contaminants (especially oil and phenol), measurement of pollution, stream purification processes and factors, plant survey and treatment, and legal considerations. Barron and Henderson (26) review the current literature of sanitation recommended for the engineer's bookshelf, including water supplies, stream pollution, sewerage and sewage treatment, and industrial wastes.

Hollis (90) stresses the need for more study on physiological and toxicological effects of both inorganic and organic chemicals in water supplies. He mentions the membrane filter for bacteriological control and techniques for recovering organic chemicals from water for study. Greenburgh (75) discusses the pollution of rivers from the aspect of preservation of fish life. He suggests procedures for sampling river water and observations to be made when loss of fish has occurred in relation to subsequent legal action. Hoak (89) discusses theory and practice in stream pollution control and stresses that the streams themselves provide the final criteria of what may be discharged to them.

A number of reports in the Public Health Service Water Pollution Series were released as summary reports for the following drainage basins: Western Gulf Drainage Basin (183), Ohio River Drainage Basin (184), Southeast Drainage Basin (185), Western Great Lakes Drainage Basin (186), and Upper Mississippi Drainage Basin (187). These cooperative state-federal reports summarize information relating to uses of water resources, pollution contributed to streams, damages to streams from pollution, benefits resulting from pollution prevention and abatement, pollution prevention measures in effect, analysis of state water pollution control legislation and pollution prevention measures required.

The Ohio River Valley Water Sanitation Commission, in its Fourth Annual Report (171), reviews the activities during 1952 of the 8-state Commission, with description of the projects undertaken, methods of operation, progress made, and objectives of the Commission. The Commission again voiced support of fast depreciation privileges for industries who must build costly treatment facilities for the prevention of stream pollution (7). It recommends passage of legislation amending the Internal Revenue Code to permit a 5-year write-off of pollution control facilities, rather than over the useful life of the equipment, to provide an incentive for industrial waste pollution abatement. The Commission attended ground-breaking ceremonies at Bromley, Ky., for a new sewage treatment plant for the Northern Kentucky Sanitation District No. 1, comprising 16 separate communities (80). The treatment plant will receive wastes from a considerable amount of industry and 136,000 people. Ramshorn (189) discusses the magnitude of the water sup-

ply and effluent problems in Ruhr region. Associations have been formed to supervise purification plants on the Ems, Ruhr, and Lippe Rivers. Self-purification has been increased on the Ruhr River by building dams and installing pumping plants to pump water from one reservoir to another upstream reservoir, thus increasing detention time.

Lowe (128) describes the water pollution situation on the Rio Grande in New Mexico. Silt loads, milling of radioactive ores, production of radioisotopes, and the increases in population are the important pollution problems in the basin. Two drainage basin reports were released by the New York State Department of Health (166) (167). One concerns the Allegheny River Drainage Basin and the other the Lake Erie, Niagara River Drainage Basin. Hess (87), in an Interstate Sanitary Commission Report, summarizes the industrial waste discharges from 306 plants distributed along 1,500 mi.. of shoreline in New York, New Jersey, and Connecticut. By mid-1954 there will be practically no raw sewage in any Class A (recreational) waters of the Interstate Sanitary Commission's area (8).

The need for a more complete definition of rights to water in relation to the many variable conditions of its uses because of the increasing use of our water resources is stressed by Harding (81). He suggests that problems should be solved without major modification of present water law concepts, with future changes in water law amplifying and refining rather than revising fundamentals. The author discusses the riparian rights doctrine and the appropriation system and summarizes the methods for acquirement of new rights, determination of existing rights, and administration of water rights.

Ohio's new Water Pollution Control Act of 1951 went into effect September 27, 1952 (9). The new act gives a 5-man board authority needed to abate pollution, including investigation, research, and education. Robinson (197) reviews the discussion on the new pollution control law at the Ohio Conference on Sewage and Wastes. McDill (141) discusses the status of the Ohio State Department of Health and the organization and activities of its water pollution control unit in relation to legislation concerning control of pollution of surface waters. Waring (236) states that adequate surveys are needed to find all areas where treatment of sewage and industrial wastes are needed. He also discusses the Ohio pollution control legislation and the financing of new works. Maryland law and policy relative to stream pollution are summarized by McKee (143). A review of legislation created by the 1949 California Legislature is presented (17). The legislation established by definition the concepts of "contamination," "pollution," and "nuisance." Control is based on a case-by-case study and analysis of water uses, rather than by a fixed rule. Baigas (23) presents an outline of the New York State pollution law and a discussion of how the law operates. Since surveys and classification of the state's waters will not be completed until 1963, no enforcement is foreseen until then. Weiss (238) presents a state-by-state summary of anti-pollution legislation, including penalties, quality standards, and special requirements. Interstate and federal pollution control is included. He also furnished the water quality criteria adopted by several interstate agencies and the composition and addresses of state water control commissions. A report (19) on the pollution of waters in New Zealand by a committee appointed by the Dominion Government was released. The report directs attention to significant conclusions regarding the effectiveness of present laws, their administration, and the consequent results of pollution.

Legislation in France for the protec-

tion of navigable waterways, standards for drinking water, control of industrial development in relation to stream pollution, and municipal control of pollution are discussed by Kempf (105). He also discusses further aspects of legislation in France to protect fish in streams from the harmful effect of industrial wastes. Walker (234) presents a resume of statutes controlling pollution of the Thames River.

Pollution control through the establishment of classes and standards is receiving increased attention. Several articles appeared in the 1952 literature relating to classification and standards.

A comprehensive bibliography (1,368 references) on water quality criteria was prepared by the California Institute of Technology (13) for the State of California Water Pollution Control Board.

Standards for sewage plant effluents adopted by the Royal Commission (Eng.) were reviewed by Roberts (196). It is claimed that the dilution formula developed from the 5-day B.O.D. values does not account for the reaeration capacity of a stream.

Milligan (147) reviewed the industrial waste effluent standards that have been adopted by various States. Phelps (177) proposes a system of stream classification based on "best usage," and the establishment of quality specifications for each class. These include a stream survey and cost considerations. Dappert (49) lists a number of principles that should be observed in developing a classification standard system for pollution control. A brief lecture on the classification of industrial effluents, their effects on streams, water supply in relation to pollution, and commercial uses of stream water is presented by Lovett (127). A report of the Mersey River Board for 1951–2 (16) divides rivers into "industrial" and "fishing" categories. It states that there are 89 different industries producing waste effluents in the Manchester area alone and pollution from such diverse wastes makes ordinary standard tests valueless. The Rivers Act of 1951 (Great Britain) set up river boards and empowers them to make surveys and to prescribe standards for both domestic and industrial effluents (14).

McCabe (139) discusses the interrelationship of air pollution and water pollution. Other reviews (10)(20) stressed the factors involved and the methods employed, the sources and characteristics of pollutants, sampling and metering techniques, regulations, and organization of water pollution control boards.

Pollution of ground water is a serious problem in certain sections of the world. Articles in the literature describe problems in Michigan (4) with pollution of ground water by small industries and oil and gas field brine and in the British West Indies (114) sewage is disposed of by pumping into borings in the coral strata.

Several articles in the literature stress the importance of stream pollution evaluation and the methods employed. Hedgepeth (85) discusses the difficulties involved in measuring pollution in order to fix standards of treatment. He stresses that no method is universally applicable and that each case must be judged on its own merits. Corti (45) discusses the conditions of modern life in Switzerland which are making it important to develop methods of protecting surface and ground waters from pollution.

Mooser (153) reviews the various types of diseases which may be spread by water, with reference to some classical epidemics from which the relations between water and disease were deduced.

Draemel (55) describes the silting of rivers in Pennsylvania resulting from widespread cutting of forests, which led to rapid water runoff and heavy soil erosion. In addition, the rivers are polluted with industrial wastes, particularly from mines. He discusses

the methods used in the conservation of rivers, especially the Schuylkill.

To reduce the pollution in the Buffalo River by dilution is the aim of five companies in the Buffalo, N. Y., area (11). They are teaming their resources to pump Lake Erie water for plant use, for subsequent discharge to the Buffalo River.

Regan (191) sketches briefly the history of the disposal of the sewage of London and follows with a description of the field work conducted from 1893 to 1952. Some of the factors which affect the condition of the tidal portion of Thames River are presented and the results of 60 years of systematic sampling are summarized with tables. Since the dissolved oxygen content at the Southern outfall has been practically zero since 1946, the London County Council is considering various plans for addition to the works so that some dissolved oxygen may always be present in the river off the outfall works. Mills (148) presents a step-by-step method for performing a pollution abatement program in tidal waters. The program is illustrated by its application to oil refinery wastes.

The problems of industrial waste disposal and pollution abatement are interdependent, especially when critical conditions exist. One method of improving the situation is by effecting pollution abatement through water conservation, and Hauck (83), Fox (67), and Howell *et al.* (91) discuss this method. Re-use, combined with waste treatment, is the key to water conservation.

Stream pollution in relation to tannery wastes is discussed in several articles in the literature (221) (192) (193) and the importance of treating these wastes is stressed. Pondaven (181) discusses the pollution of streams by distillery wastes and Coogan (43) presents factors which influence pollution problems associated with the operation of sugar factories. A program of surveying stream conditions to determine the effect of grinding operations on water in streams is being conducted.

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SIGNIFICANT TRENDS AND SUMMARY

The literature review should serve the major purposes of (a) giving a digest and summary of the year's accomplishments, developments, and trends to those who have little time or facility to follow the current literature; (b) furnishing a ready reference for further search and inquiry to those who are interested in a particular phase or paper; and (c) evaluating the literature critically, indicating trends, and calling attention to needs and future developments.

That the review is comprehensive is attested to by the listing of 634 references. It is possible that a few significant references have been missed, despite the diligent and conscientious search of 24 reviewers of various sections. At the same time, the list of references could be increased by including contributions of minor significance. However, a deliberate effort has been made to eliminate such references as much as possible.

The listing of references at the end of each of five major topical divisions is for the accommodation of readers interested only in certain phases of the review. A comparison of the number of references under each division of the present review with those in 1951 is as follows:

Section	1952	1951
Analytical methods	55	52
Sewage	129	201
Radioactivity	51	94
Industrial wastes	149	164
Water pollution	250	256
Total	634	767

The decrease of 133 references over the previous year is not necessarily significant of a decrease in the number of published papers, because of the greater selectivity practiced this year. It is, however, significant that the greatest decrease is in sewage.

A comprehensive coverage need not necessarily be incompatible with the critical evaluation of the papers and yet there is a tendency to subordinate and sacrifice critical evaluation and significant trends in a rapid recital of a great number of references. An attempt is made in this section, therefore, to point out such trends and significant contributions from the mass of material covered.

Analytical Methods

The detection and identification of small quantities of organic materials present in water by concentrating it by filtration calls attention to the need of newer chromotographic, spectrophotometric, and other methods for the study of the specific nature and quantities of the various organic compounds present in sewage and industrial wastes and the intermediate and other metabolic products produced in the various treatment processes from the standpoint of physiological and toxicological effects.

A method of great promised usefulness in the enumeration of bacteria has been the development of membrane filters and their application to the detection of specific bacteria in water and sewage.

A need exists for a more accurate evaluation of residual chlorine in relation to different levels of coliform organisms in the effluent. The amperometric method may furnish certain advantages over existing methods.

There is need for a compilation of the B.O.D. of various organic chemicals that might be found in sewage and industrial wastes, as well as for an accurate and reliable method of determining the quantity of various detergents.

Sewage

A promising development in settling tank design with radically sloped bottoms shows some advantage over conventional tanks.

The trend in biological filtration has been in the direction of a more precise evaluation of the effect of a number of factors (such as temperature, pH, recirculation, ventilation, loading, and rate of distributor rotation) on the performance and efficiency.

An additional modification, designated as the "Spirovortex" method, and a further study of aeration in a high-oxygen atmosphere, constitute the new developments in the activated sludge process. Further studies in air diffusion methods and reoxygenation capacities of different methods of aeration are in the direction of improved utilization of air.

Additional fundamental studies on the effect of detergents on various treatment processes, and in particular on frothing in aeration tanks, have been made. It has been shown that, in addition to detergents, other factors, such as solids concentration in the mixed liquor and length of aeration period, play a role in frothing.

It is of interest to note that from a number of different sources, independent investigations have shown the deleterious effects of sulfides and sulfites on sludge digestion. Sulfates also have an inimical action if present in sufficient quantities, since they are readily reduced to sulfides. Methods of overcoming this deleterious effect of sulfides on digestion have not been entirely successful or practical.

A new impetus is given to the treatment of sewage by lagooning by the fundamental studies under way in the University of California, where the factors involved in establishing a successful symbiosis between algae and bacteria are being determined. The recovery of algae cells as animal feed, if successful, should make this method of treatment more attractive.

Industrial Wastes

A number of examples of recovery of by-products are evident in the literature. Some of these are (a) recovery of vitamin B_{12} from activated sludge, (b) recovery of animal feed from canning wastes, (c) recovery of oil from petroleum refining wastes, (d) recovery of grease from wool scouring wastes, and (e) recovery of gas liquor as fertilizer.

The number of installations utilizing spray irrigation as a method of disposal of cannery wastes has been increasing. The influence of a number of fundamental factors remain to be worked out, however, before the process can be put on a sound basis.

In the dairy waste treatment field, interest and trend seems to be in the direction of aerobic process development. It remains to be seen what the effect on the oxygen balance of the stream will be when the effluent containing the dispersed bacterial cells, which have been shown to have a considerable endogenous respiration oxygen demand, is discharged. The recovery of the bacterial cells as foodstuff and as a source of vitamins should be an added benefit, besides the effect of their removal on the oxygen balance of the stream.

Additional information from installations embodying biological processes

for the treatment of antibiotic wastes is becoming available. Biological treatment is also being used for the treatment of wastes containing formaldehyde and petroleum refining wastes.

There is considerable information accumulating on the use of ion exchangers for the removal of inorganic toxic materials, such as Cu, Zn, Cr, and Ni, with and without recovery of the metals.

Destructive catalytic oxidation for the treatment in aqueous or vapor phase of wastes containing low concentrations of organic compounds is outstanding.

An example of a cooperative solution of a waste disposal problem is the study of the oxidation of phenol in ammonia still wastes by chlorine, chlorine dioxide, and ozone by Orsanco. Gary, Ind., is still another example of satisfactory solution of a problem by cooperation between industry and municipality in the treatment of ammonia still wastes. The attempts of national trade associations to solve the problems of their respective industries is contributing to the information available for pollution abatement. Noteworthy developments are the aeration process for the treatment of kraft mill effluent and de-inking wastes, the evaporation process for sulfite pulping liquors, and laboratory investigations on the treatment of cook and wash liquors from rag, rope, jute, specialty products, and white water.

In general, industrial waste treatment is going through a period of intensive basic and applied research for the development of new methods of treatment and firmer establishment and application of old methods.

Considerable information is being obtained for the treatment and disposal of wastes arising from production of radioactive materials. These same radioactive materials have been successfully used as tracers for determining flow patterns in streams, tanks, and pipes.

Water Pollution

Attention is called to the various references dealing with the isolation of pathogenic bacteria from polluted waters and sewage. Additional evidence is being obtained of the ability of water bacteria to produce antagonistic substances and of bacteriophages under laboratory conditions, but whether these substances are actually responsible for the decrease of bacteria under the natural environment is open to question. The rapid decrease of coliform organisms in sea water has been accounted for by dilution, bactericidal action of sea water, and predation.

Special attention is called to the biology sub-section of the Water Pollution Section for those interested in fish mortality, and bio-assays. The coverage of foreign literature pertaining to this subject is extremely valuable and comprehensive. In addition, there is considerable information in this section on the role played by aquatic plants and animals, the effect of various wastes on them, and their use in classifying pollutional zones in the stream. From a number of independent sources comes evidence of toxicity of certain types of algae to animals.

A number of extensive stream surveys have been made, but the trend seems to be to pass from the fact finding stage to the practical control of pollution abatement. The interest in effluent and water standards and stream zoning continues, but special mention must be made of the publication of water quality criteria by the California Water Pollution Control Board, which takes the viewpoint of case-to-case study of each problem of pollution with the abatement requirements to be based on the beneficial use to which the water under consideration is to be put.

Sewage Works

REHABILITATION OF THE SCHENECTADY SEWAGE TREATMENT PLANT *

By Edward S. Ordway

Principal Engineer, Havens and Emerson, New York, N. Y.

The remodeling and modernizing of an old sewage treatment plant involves many unusual problems seldom, if ever, encountered in entirely new construction. In cases where structures are sound and readily susceptible to remodeling, it is a thoroughly satisfying experience to see the old structures, built so well years before, remodeled and given new life for many more years of useful service. The feeling is one of worth-while economic gain.

A case in point is the rehabilitation of the sewage treatment plant of the City of Schenectady.

Original Plant

The original plant, located on the east bank of the Mohawk River, was first placed in operation in January, 1915. It was designed to treat an average flow of 12.0 m.g.d. as contributed by a population of about 90,000 persons. It consisted of hand-cleaned bar racks, 9 settling tanks of the two-story Imhoff type, 3 automatic-siphon dosing tanks, 3 standard-rate fixed-nozzle trickling filters having 5-ft. depth of stone. Filter effluent flowed by gravity to the river without final sedimentation or humus tanks. An emergency effluent pumping station, located on the river bank, was provided to pump plant effluent to the river during flood stages. Buildings were provided for office, plant laboratory, and storage space for tools and equipment. Open sand drying beds were provided for dewatering digested sludge from the Imhoff tanks.

The annual report for 1939, which celebrated a quarter century of operation, called this plant "one of the first modern sewage treatment plants of the country." The following analytical data on the characteristics of the raw sewage and plant effluent, taken from that same report, give evidence of the excellent performance obtained:

	Raw Sewage p.p.m.	Final Effluent p.p.m.
Total solids	541	375
Suspended solids	177	36
Settleable solids	152	—
B.O.D., 5-day	119	16

In a 1947 study of the sewage disposal problem of the city, it was estimated (there were no flow meters in the old plant) that the daily average flow reaching the treatment plant was about 10.0 m.g.d. and that another 5.0 m.g.d., or one-third of the total sewage flow, was being by-passed directly to the river at one point or another within the city.

The basis of design for treatment plant improvements was predicated upon the following general conditions:

1. Regulations of the State Department of Health, which permitted use of plain sedimentation.

2. The expressed desire of city officials to make maximum use of existing facilities.

3. The pressing need for additional trunk sewer capacity so that all sewage

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flows could be delivered to the treatment plant.

4. A desire to continue development of a market for sludge as fertilizer.

As a result of study of population growth, water consumption, and sewage flows, it was concluded that the proposed plant expansion should be designed on the basis of an average daily flow rate of 20.0 m.g.d. It was expected that this rate would obtain in about 1970, coincident with a tributary population of approximately 125,000 persons.

Modernized Plant

The modernized treatment plant, which is presently nearing completion, consists of mechanically-cleaned rack screens, grit removal, plain sedimentation, and chlorination. Sludge from the settling tanks will be digested in separate, heated digestion tanks; dewatered on vacuum filters; heat-dried in a flash drier; and either bagged for sale as fertilizer or destroyed by burning.

The existing trunk sewer is approximately 8,400 ft. long and has a slope of 0.0194 ft. per hundred. The lower portion is a reinforced concrete box 6 ft. wide, 3 ft. 7 in. deep, and of 20.33-sq. ft. cross-sectional area.

In the old plant the flow line was maintained at a high level. The adverse effects of this high level were two-fold; first, during periods of high flows the outlet became choked, with a resultant decrease in carrying capacity; and, second, the extremely low velocities which obtained during low flow periods resulted in a deposition of sewage solids in the conduit. Actually, when the trunk was dewatered, this accumulation measured 17 in. in depth.

Hydraulic studies of this line revealed that, when flowing completely full, the existing conduit has a capacity of 23.0 m.g.d. When the flow line is kept below the roof, however, it has a capacity of 30.0 m.g.d., due to favorable outlet conditions. This is equal to 200 per cent of present average flow rates and 150 per cent of estimated 1970 average flows. It was apparent that this capacity would be adequate for some years to come except for extreme storm conditions. A siphon overflow is contemplated at the upper end of the trunk to by-pass storm flows in excess of 30.0 m.g.d.

The conclusion of these studies was in general agreement with a similar in-

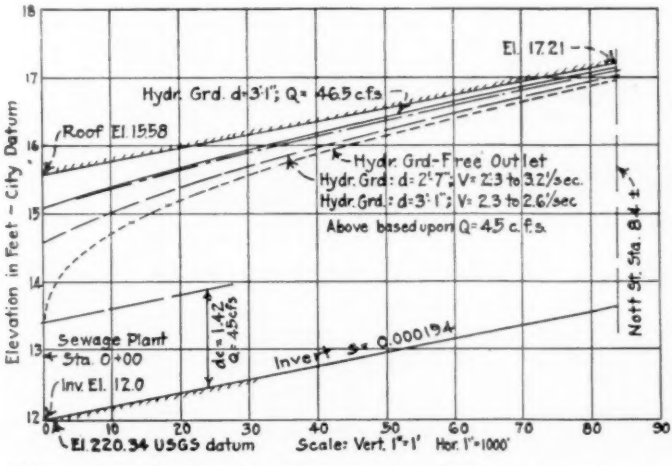

FIGURE 1.—Calculated flow lines in existing Schenectady trunk sewer.

FIGURE 2.—Old Imhoff tanks prior to alterations.

vestigation conducted by engineering personnel of the city in 1933. Both indicated the necessity for lowering the flow line at the treatment plant to insure free-flow conditions during periods of high flow and sufficiently high velocities during low flows to prevent deposition of grit and heavy sewage solids. The hydraulic gradient of the remodeled plant has been chosen to accomplish these results. Figure 1 indicates some of the flow conditions covered by the studies.

At the entrance to the plant, the

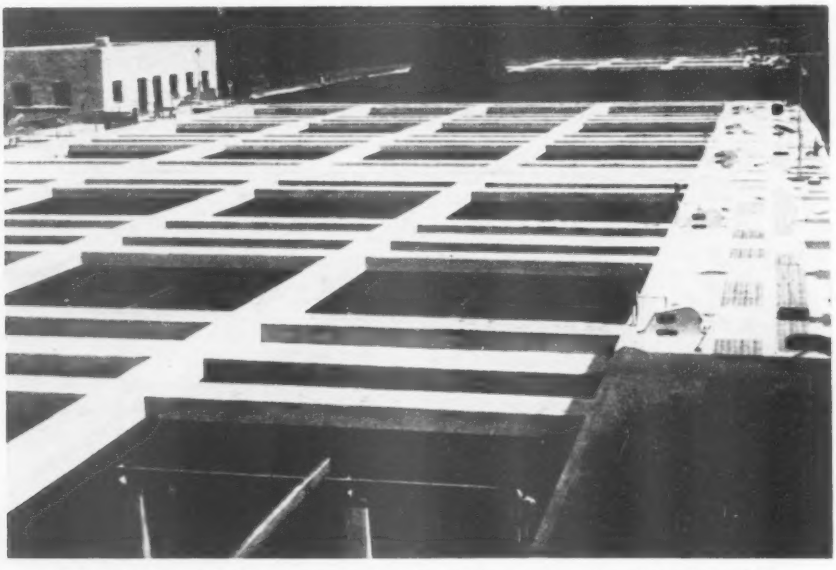

FIGURE 3.—Imhoff tanks converted to settling tanks to handle greater flow.

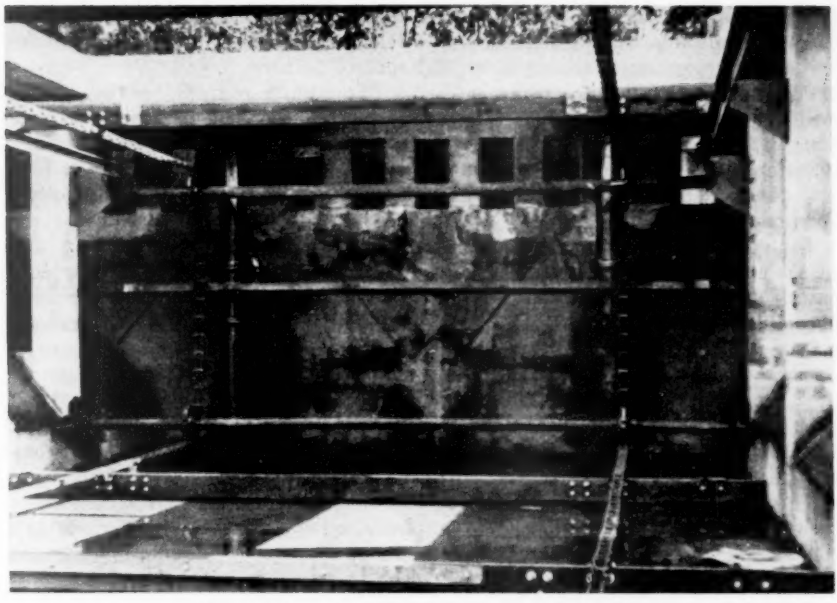

FIGURE 4.—Inlet end of remodeled settling tank.

sewage passes through two mechanically-cleaned rack screens each 5 ft. wide and having 1-in. clear openings, followed by a 30-ft. square detritor having a capacity of 10 to 40 m.g.d. for the removal of grit. It then passes into the inlet channels of plain sedimentation tanks, which are the result of alterations and additions made to the old Imhoff tanks. Figure 2 shows the old tanks prior to start of alterations. Since these old tanks were much shallower than the usual Imhoff tank, new flat-bottom slabs were located at about the top of the old sludge hoppers; division walls were knocked out; new inlet and effluent channels were added; continuous flight sludge collectors were installed; and new walkways were built around the top of the tanks to replace the rather meager ones removed from the old tanks. Figure 3 shows the same tanks near the completion of the alterations.

The tanks, as remodeled, are somewhat unusual, as they represent quite a departure from the ordinary mechanically-cleaned plain sedimentation tanks. They are 94 ft. 8 in. long, 18.0 ft. wide at the bottom, and 29.0 ft. wide at the top, with an average water depth of 8.85 ft. Because the flight skimmers are only effective over the center 18 ft. of the surface, water sprays (using settled sewage) are installed along each side of the tanks to direct floating matter into the path of the collectors. Figure 4 shows the inside of the remodeled tank looking toward the inlet end.

The converted tanks are expected to provide a 2-hr. detention period for a flow of 16.5 m.g.d. Space is available for two additional conventional settling tanks when required.

Chlorination Facilities

Settled sewage will be chlorinated by two 6,000-lb. machines as it passes through a chlorine building. Two multi-pass chlorine contact tanks will provide a 15-min. detention at estimated 1970 maximum flow of 40.0 m.g.d.

A Venturi meter is located in the chlorine building with a register for indicating-recording-totalizing flows of settled sewage. Chlorine dosing rates will be automatically controlled from the Venturi meter. Although post-chlorination is expected to be the normal practice, provision has been made for pre-chlorination if desired.

In addition to oxygen breathing masks and large-capacity exhaust fans installed in the chlorine building, a special enclosed pit is provided where a leaking 1-ton container can be placed by the monorail. A hydraulically-operated aspirator is provided to withdraw escaping gas and discharge it, largely in solution, into a storm drain and then into the river.

This equipment is somewhat of a departure from usual procedure, but is considered worth-while since it eliminates the necessity of rolling a leaking container into the open air where the gas could be blown about and might become a hazard.

Chlorine contact tank effluent is discharged by gravity to the river through a submerged outfall, except during flood stages, when it must be pumped.

Sludge Handling

Sludge and skimmings from the settling tanks are to be pumped to four circular digesters. Each tank is 65 ft. in diameter, has a sidewall depth of 18 ft., and is protected from the weather by earthen embankments. These will provide 2 cu. ft. per capita capacity. All are equipped with conventional-type floating covers, automatic supernatant selectors, and external sludge heaters arranged to burn sludge gas or fuel oil.

Some of the most troublesome problems of a sewage treatment plant frequently develop in the handling, digestion, and disposal of sludge. One seldom, if ever, hears an operator or plant superintendent complain of too much flexibility in the control piping of digestion tanks. When the going is rough, however, all too often one finds the air "blue" because of lack of some relatively simple cross-connection or control feature.

The piping comprising the control system of the new digestion tanks is somewhat more extensive than many others, but it is felt that the added flexibility of operation afforded justifies the cost involved.

All piping, control equipment, and heaters are located in a digester control chamber nested between the four tanks. The piping system is arranged to permit operation by either single- or two-stage digestion. Sludge or supernatant can be recirculated within any tank or between two different tanks, either directly or through one of the heaters. Digested sludge can be sent either to the old sand drying beds or to the vacuum filters in the sludge disposal building. Supernatant can be pumped to the plant inlet or to the old sludge drying beds.

Gas meters are included for measurement of the quantities of gas produced in each tank and the quantity used by the sludge heaters. Gas in excess of requirements for sludge heating can be burned in the sludge incinerator. A waste gas burner is provided for disposition of excess gas when the incinerator is not in service.

A tunnel connects the basements of the digester control chamber and the sludge disposal building. This tunnel not only provides underground access from one building to the other, but also contains all interconnecting piping.

Digested sludge will flow from the digestion tanks to a sludge sump in the sludge disposal building directly below the vacuum filter installation. The sludge will be conditioned with ferric chloride and lime, dewatered on the vacuum filters, and discharged by belt conveyor to the flash drier.

Vacuum Filters and Incinerator

The vacuum filter installation consists of three units, each 6 ft. in diameter by 6 ft. long, having a total

area of 339 sq. ft. Space is provided for the addition of a fourth unit when required.

Assuming that there will be a 30 per cent reduction in solids during digestion, and making allowance for conditioning chemicals, it is expected that the 1970 solids loading will be about 1,400 lb. per hour, based on 14 hr. of filter operation per day. Resulting filter loadings, expressed in pounds of dry solids per hour per square foot of vacuum filter surface, under present and future conditions, are summarized as follows:

No. of Filters	Present	Future
2	4.7	6.2
3	3.1	4.1
4	—	3.1

The sludge incinerator will be capable of burning 1,500 lb. of dry solids and evaporating 3,500 lb. of water per hour. The design contemplates delivery of a filter cake containing 70 per cent moisture.

The incinerator unit installed is of the flash drying, mixed-combustion type, which can be operated for evaporation of moisture from the sludge so that it can be used or sold as a fertilizer base. It can also be operated for high-temperature combustion of the burnable portions of the sludge, leaving a non-offensive mineral ash, which will be pumped to an ash lagoon for dewatering.

When operated as an incinerator, the fuel value of the sludge itself is expected to be generally sufficient for maintenance of suitable combustion conditions. When operated as a drier, sludge gas, fuel oil, or a combination of both will be used as fuel for evaporation of moisture from the sludge cake.

A promotional campaign developed a sizable local market for the air-dried sludge of the old plant. It is the intention to renew and intensify this campaign for development of an even bigger market for the heat-dried sludge. As a result, a bagging machine is provided, together with a monorail hoist, storage space for the bagged product, and other facilities essential to such an operation.

Method of Financing

The cost of the modernization program described is to be financed through sewer service charges levied against properties served by the sewer system. During the past year these charges have been collected on the basis of temporary rates, which were put in force pending completion of a detailed study and establishment of rates suitable for present and future requirements.

DISCUSSION

By Morris M. Cohn

City Manager, Schenectady, N. Y.—Editor, "Wastes Engineering"

The conversion of the Schenectady Imhoff tanks to mechanically-cleaned settling tanks should serve as a challenge to the designers of new facilities for old plants to balance engineering with economics and, wherever feasible, to save and convert old units into new ones. The surprisingly good condition of the underwater portions of the Schenectady Imhoff tanks, after 38 years of service, should be an incentive for other plants to "look before you scrap."

Over and above the engineering and financial benefits of converting old facilities to new units, there is the public appeal value of a remodeling project. There is something about the rebuilding of a structure which appeals to an old-fashioned sense of economy. In

many cases, cities which must now rebuild sewage treatment plants were pioneers in the field, whereas other cities were doing nothing about sewage treatment. If the pioneering cities feel that their original investments are not totally lost, but are being used to save construction costs, the new investments will be more favorably received. It must be understood that some pioneering cities are faced with reconstruction, enlargement, and modernization projects, while neighboring communities are still hesitating about construction of their first treatment plant.

In the case of Schenectady, the saving of the shell of the old Imhoff tanks spared the city some very bad excavation conditions, which originally caused the tanks to be built as perhaps the shallowest Imhoffs in municipal practice. In addition to this saving, a major economy in construction was achieved by lowering the flow line through the treatment plant and avoiding the necessity for reconstructing a 1½-mi. long conduit through difficult terrain and a heavily developed area. This trunk sewer has been seriously surcharged at flows of about 10 m.g.d., but will safely carry a flow of 30 m.g.d. under unsurcharged conditions made possible by the new flow line in the settling tanks. Here is a dramatic example of the point that designers must consider the economics of every phase of a plant reconstruction project. One word of caution is indicated; although economies may be achieved by reconversion such as has been praticed at Schenectady, it is essential to point out that the work of the designing engineer is more difficult on a reconstruction project than on a totally new one. Added to this complication is the fact that a redesigned plant does not always give the same geometrical perfection which can be achieved when a new works is designed and constructed on a new site.

One of the features of the Schenectady plant deserves particular mention. The old plant provided secondary treatment by means of trickling filters for approximately 55 per cent of the city's sewage flow. Now the State Water Pollution Control Board is willing to "swap" primary treatment of all of the sewage flow for secondary treatment of only a part of the flow. Actually, in terms of removal of B.O.D. and suspended solids, it might easily be demonstrated mathematically that the old treatment facilities were providing as good over-all protection for the Mohawk River as the new plant will provide. This, of course, is a broad categorical statement, because the elimination of heavy raw sewage solids will be a great boon to the river, as will seasonal chlorination of the effluent. In addition, the novelty of providing trickling filter treatment without final settling facilities resulted in the periodic unloading of much humus solids from the filters directly into the river.

This "swapping" of secondary treatment for primary treatment, rather than being inexplainable, is an intelligent application of the principle of pollution control by the use of a stream classification system, because the Mohawk River will require only primary treatment to meet the classification which will be imposed upon it by the State Water Pollution Control Board after its engineering surveys have been completed. But the stream will need primary treatment by all communities, not by only one. Streams cannot be cleaned up by "spot" treatment. The solution for pollution can be achieved only by concerted action. Unified action will clean up an entire stream basin and will avoid the inequities of one city "doing it all."

There is still another point to be made about the Schenectady project, which was so well described by Mr. Ordway. A plant must be designed to meet the needs of the community, in

addition to the needs of the stream. The decision to provide for alternate sludge drying or sludge incineration came as a recognition of the fact that a reasonably active market had been developed for crude air-dried sludge by dint of years of promotional effort among farmers, produce growers, and home owners. In addition, the city had pulverized small amounts of sludge and sold the material under a trade name that de-emphasized the word "sludge" and stressed the organic soil-conditioning value of sewage residue. Because of the expected availability of a market for heat-dried soil building material, provision has been made for drying the sludge by flash drying and bagging it under the name of "Orgro." It is hoped that the name of the product will catch the fancy of the many gardeners in the Schenectady area.

As previously mentioned, many of the treatment plants now in service in the United States need rebuilding or will soon require some degree of reconstruction. It is significant that these changes will involve not only structural reconversions, but also conversions of the basic process of sewage treatment. The predominating change will be from manual operations to mechanized operations. The details involved in the conversion of the Schenectady plant will not necessarily apply of course, to other plants.

It should be noted also that no reconstruction job can be solved by taking a set of plans off the shelf and converting them to local conditions. Each conversion job is a challenge in itself. However, the fact that the Schenectady conversion project was successfully designed, safely constructed, and will probably be effectively operated should encourage other communities to thoroughly investigate the engineering and economic feasibility of this principle.

1952 MUNICIPAL PLANT CONSTRUCTION

The Nation's progress in reducing the pollution of its water resources through construction of municipal sewage treatment plants has been summarized in a report recently released by the U. S. Public Health Service, Department of Health, Education, and Welfare. The report indicates that in 1952 a total of 515 communities in the United States awarded contracts involving an expenditure of $137,000,000 for this type of construction. Of these contracts, 314 were for new plants costing $78,419,556 and 201 were for additions, enlargements, or replacements of existing plants, costing $58,789,133.

The report compares the 1952 construction rate with the annual rate of from $450,000,000 to $500,000,000 estimated to be required over a 10-year period to bring the pollution caused by municipal wastes under reasonable control. The 1952 total of $137,000,000 is less than that for any year since 1948, and also falls short of the long-term average of $141,000,000 for the period 1915–1950.

ALGAE SYMBIOSIS IN OXIDATION PONDS *

III. Photosynthetic Oxygenation

By William J. Oswald, H. B. Gotaas, Harvey F. Ludwig, and Victoria Lynch

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Organic matter decomposes rapidly in water because of its ready availability to microorganisms and their enzymes when in solution. Saprophytic microorganisms convert complex suspended or dissolved organic compounds to simple substances such as carbon dioxide and ammonia. Because oxygen is the ultimate hydrogen acceptor in the oxidations that accompany these rapid conversions, it frequently becomes so depleted that aerobic oxidation is halted.

Secondary sewage treatment processes involve the oxidation of dissolved or colloidal organic matter in settled sewage by microorganisms under conditions wherein oxygen does not become depleted. Most of these, such as the activated sludge process or the trickling filter process, are so designed that oxygen from the atmosphere is forced to enter the liquid phase at an accelerated rate.

Photosynthetic oxygenation is a completely different method of supplying the needed oxygen. Photosynthetic oxygenation may be defined as the production of oxygen through the action of light on the chloroplastic tissue of microscopic green plants, growing dispersed in the aqueous medium. This oxygen is produced by photosynthesis and derived from the decomposition of water. Its availability is independent of the physical laws normally governing oxygenation from atmospheric sources. Bodies of water containing green algae may attain supersaturation with dissolved oxygen up to three or four times the normal saturation value of water when in equilibrium with the atmosphere.

Sewage Oxidation Ponds

Sewage lagoons or oxidation ponds have been employed by sanitary engineers in the United States, mostly in the West and Southwest, in an effort to make use of photosynthetic oxygenation together with natural reaeration. Figure 1 is a schematic representation of such a pond.

When sewage enters the lagoon, bacteria are already at work. Decomposition of the sewage organic matter progresses swiftly. Carbon dioxide and ammonia are produced, some of which escapes to the atmosphere. Oxygen is consumed at a rapid rate, and when pond loadings exceed certain limits, complete oxygen depletion occurs, particularly in the initial sections of the pond. These various actions make up the bacterial phase. Field observations indicate that it is normally completed in 10 days, provided continuous aerobic conditions are maintained.

Following the period of bacterial action, and when light and temperature are satisfactory, algal populations appear in significant numbers. Photosynthetic oxygenation occurs, and should the water become supersaturated with oxygen, gaseous oxygen will escape to the atmosphere. The algae fix available carbon (that is, carbon

* Presented at 25th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; New York, N. Y.; Oct. 6–9, 1952.

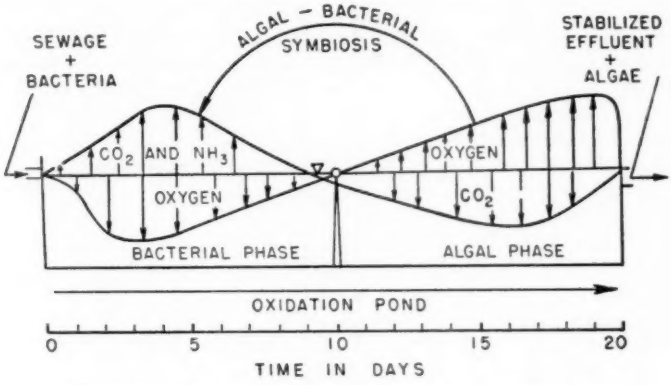

FIGURE 1.—Schematic representation of an oxidation pond.

dioxide made available from the alkalinity of the water, by bacterial metabolism, or by solution from the atmosphere). Available nitrogen is synthesized into cell protein. Finally, the mixed liquor, comprised of spent sewage and a large amount of algal cells including their excretory products, is discharged.

The efficiency of such a system leaves much to be desired. Oxygen is produced and wasted at a time and in a place where it is not needed. Also, from the point of view of algae yield, carbon dioxide is produced and lost that might be utilized to promote growth of additional algae. Moreover, valuable organic and inorganic substances are finally discharged and wasted.

This picture is typical of many actual pond installations. Wind currents and wave action tend to promote some mixing of the bacterial and algal phases. In warm and sunny weather the algae frequently invade the bacterial phase, effecting oxygenation that accomplishes sewage treatment more quickly. However, due to the long over-all detention period of the system, such algae become old and fat (3), frequently dying and contributing their cell material to the pond load, cancelling out their earlier beneficial effect.

As indicated by the upper arrow in Figure 1, ideal pond treatment would involve an overlapping of the bacterial and algal phases, forcing a symbiosis wherein the algae supply the oxygen demand of the bacteria through photosynthetic oxygenation, and bacteria supply the algae with needed carbon, nitrogen, and other products of sewage decomposition. Recirculation has been used as a practical means for partial accomplishment of this objective.

Integration of Bacterial and Algal Phases

A complete overlapping or integration of bacterial and algal phases is seldom encountered in nature. This is probably due to competition for nutrients, and in some cases even to antibiotic activity (1).

Closed Continuous Systems

Figure 2 presents two sets of data from 20-day laboratory tests conducted with a specially designed culture tube called a "symbiocon." More completely described elsewhere (2), the symbiocon is a closed system simulating a "balanced aquarium" for bacteria and algae, in which the atmosphere is eliminated as a factor in gas exchange.

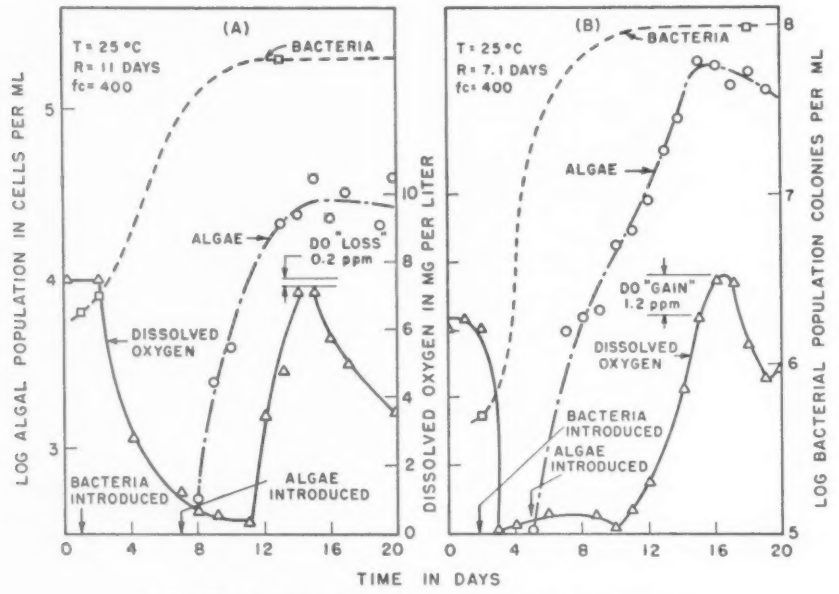

FIGURE 2.—Algal-bacterial symbiosis in a closed system.

Figure 2 shows that a symbiosis of algae and bacteria can be maintained in a closed system, to which nutrient sewage is being continuously added at a constant rate, and from which an equivalent volume of the culture is continuously withdrawn.

Both diagrams show that as algae grow, oxygen is produced, and that after completion of the log phase of algal growth oxygen depletion occurs. The higher rate of loading in Figure 2B produced higher bacterial and algal populations, and more "gain" in dissolved oxygen at the peak of oxygen production.

A state of dynamic equilibrium is exceedingly difficult to obtain in a symbiocon, indicating the complex interdependence of the variables affecting overlapping algal-bacterial growth. The symbiocon technique has just been developed, and further studies are underway to determine the best operating conditions. It is presently believed that an equilibrium that can be maintained indefinitely in the symbiocon can obtain only when each of a number of major variables is held within close but as yet unknown limits.

Open Continuous Systems

Equilibrium is readily obtained in open continuous systems termed "growth units." These are large culture tubes having facilities for light, temperature, feed rate, and sterility control (3). They differ from symbiocons in that instead of being sealed from the atmosphere, bubbling air is utilized to maintain mixing in the tubes. Open units such as these are more simply operated than symbiocons. Moreover, they attain an equilibrium that may be continued indefinitely (4). Because of this, growth units are more versatile than the symbiocon for studying such physical variables as light, temperature, and retention periods.

Variables Affecting Symbiosis

The major variables influencing symbiotic growth of bacteria and algae are retention period (determined by

the rate of feed), sewage strength (including characteristics), light intensity and periodicity, temperature, and the bacterial and algal species and activity. All of these in one way or another influence (a) the growth of bacteria; (b) populations and general physiology of the algae, including their age and physical appearance, composition of cell material, chlorophyll formation, rate of oxygen production, rate of respiration, rate of uptake of carbon dioxide and nitrogen and inorganic ions, and the total density and yield of algal cell material; and (c) the overall sewage treatment accomplished in such systems.

Effects of Varying Retention Periods

Because bacteria and the algae studied multiply by binary fission, similar rules govern the populations of each produced in batch cultures as a function of time. As shown in a previous paper (2), the population attained in a batch culture at a given age corresponds roughly to the equilibrium population in a continuous culture having a retention period equal to that age. To obtain precisely the same populations, the retention period for the continuous culture must be slightly greater than the age of the corresponding batch culture. The population in the continuous culture is maintained at its equilibrium value, whereas the batch culture population falls off as multiplication ceases.

Bacterial Activity

In Figure 3 the data obtained from a batch culture of bacteria, and from batch and continuous cultures of algae, grown in the test sewage are utilized

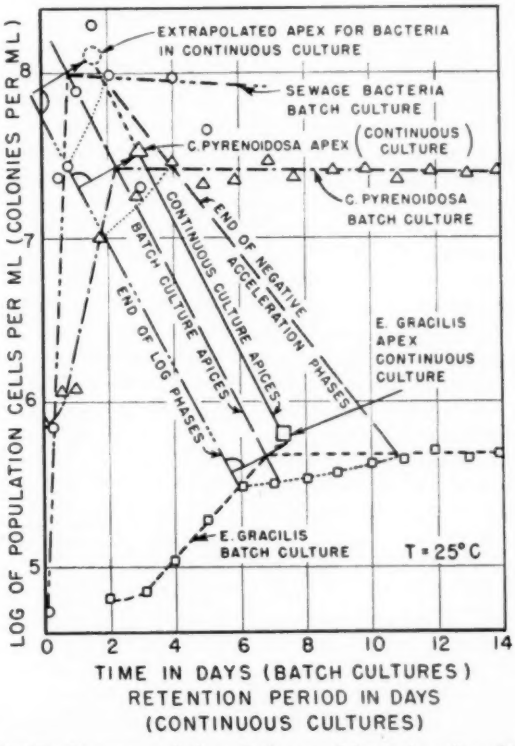

FIGURE 3.—Maximum population of algae and bacteria cultured in sewage.

to estimate the apex population for a continuous culture of comparable bacteria. The result indicates the maximum bacterial population to be approximately 10^8 occurring at $R = 1.5$ days.

In continuous cultures, the maximum yield of algae occurs at a retention period about one-sixth of that for maximum population (1)(3). Assuming this relationship applies also to bacterial cultures, the maximum bacterial activity (that is, maximum oxygen uptake) should occur at $R = 0.25$ days. This value agrees with the time required to obtain maximum rate of oxygen uptake in the Warburg test made with sterile domestic sewage at 25° C., as previously noted (3). It also checks closely with the detention times of 4 to 8 hr. used in the operation of activated sludge plants.

Algal Activity

Other factors being constant, the most favorable environment for algal growth in continuous cultures is obtained at short retention periods. Under these conditions algal growth is maintained in the logarithmic phase. The cells are large, rich in chlorophyll, low in carbohydrate and fat, and produce algal cell material rapidly. Oxygen production per cell is high. Even though the cell population may be low, the total net oxygen production and the total algal yield both attain their highest values at a retention period approaching the minimum regeneration time of the specific algal species. Under such conditions the daily yield of algae is an easily measured and quite accurate criterion of daily oxygen production.

As the retention period increases beyond this point, the algae enter a negative acceleration phase of growth. Multiplication is slower and may cease entirely for many of the cells. Other cells continue to multiply, but their daughter cells have diminished size. Chlorophyll content per cell is reduced and, therefore, photosynthetic oxygen production is retarded. The total respiratory requirement is increased because the mass of cells has increased (although the individual cell respiratory requirement may have remained low). The net oxygen yield falls off rapidly as retention period continues to increase.

At very long retention periods, beyond the end of the negative acceleration phase, the total cell population has not decreased, but the size of the individual cells has increased to maximum. In the case of both *Euglena* and *Chlorella*, further increase in retention period causes a final dropoff in population due to autolysis, cell senescence, and death. Algae existing in this phase have a high respiratory requirement per cell. Although autolysis is occurring, the cell population remains high and chlorophyll content is very low; hence, the total oxygen uptake of the algae may exceed the amount of oxygen produced in photosynthesis.

With both *Euglena* and *Chlorella* it was found that the cell-free supernatant effluent from culture units had relatively low 5-day Warburg B.O.D. values almost independent of retention period. Chemical analyses of these effluents showed that they contain large amounts of carbon, hydrogen, and nitrogen. The C/H ratios or C/N ratios of this material give little indication as to its nature, but the B.O.D. tests indicate that it is highly stable and hence probably highly oxidized.

Effects of Sewage Strength and Composition

In all of the studies it has been consistently observed that natural sewages with higher 5-day B.O.D. values support greater populations of *Euglena gracilis, Chlorella pyrenoidosa, Schenedesmus obliquus,* and *Chlamydomonas* sp. than lower strength sewages. The presence of more carbon, nitrogen, and other critical elements seems to produce this effect, but there are indications

that the ratios of these substances may also be important. Preliminary to the light studies reported hereinafter, repeated attempts to grow *E. gracilis* on a synthetic sewage containing higher concentrations of all known critical elements than natural sewage, and having a higher B.O.D., resulted in only marginal growths. On the other hand, in similar tests, *Chlorella* growths in this synthetic sewage were more abundant than in normal sewage. Also, magnesium may be a critical ion in certain cases, because it is an essential part of the chlorophyll molecule.

Study of Varying Light Intensities

These experiments were made with *E. gracilis*, employing the open-type continuous growth units. A constant and sterile sewage of low B.O.D. was used as the substrate,* so that culture densities would remain relatively low and thus minimize light absorption. The tests were made at a fixed retention period of 7 days, which was selected after preliminary work had shown that *Euglena* populations cannot be readily maintained at low light intensities at shorter retention periods. Temperature in all of the series ranged between 24° and 26° C., and individual series varied ± 0.5° C. from the mean.

Light intensities were estimated on the basis of the number of new 30-watt daylight fluorescent lights utilized. With a single light the interpolated intensity within the growth units is 400 ft.-c. (foot-candles). Interpolation is made between the measured intensities at the front and rear surface of the culture tube with respect to the light source. This intensity is measured with a photocell, galvanometer, and calibrated variable light source. Intensities of 100 and 200 ft.-c. were obtained by blacking out proportionate strips of the fluorescent light. Duplicate bulbs were alternated to cancel minor differences in intensity among different bulbs.

Euglena cultures were started on sterile sewage in Erlenmeyer flasks, and after 10 days were transferred to the growth units and inoculated with sewage bacteria as previously described (2). Sterile sewage was then added to the culture at a rate corresponding to the selected retention period until full culture volume was attained. Air was bubbled through the cultures continuously at the rate of 500 ml. per minute. After full volume was reached, one-seventh of the culture was removed daily and replaced by sterile sewage. Evaporation losses were made up with sterile distilled water before withdrawal.

Daily tests for cell population, cell volume, pH, and alkalinity were performed on effluents until changes were negligible, indicating a state of equilibrium. The entire culture was then sacrificed in order to have sufficient experimental material for complete testing.

In addition to the tests made with the natural sewage, certain comparable tests were made with a stronger synthetic sewage * at a retention period of

* This sewage was different from that for the retention period studies. After processing as described elsewhere (3), it had the following characteristics: pH 9.5, total alkalinity 175 p.p.m., bicarbonate alkalinity 115 p.p.m., manometric B.O.D. (5-day, 25° C.) 90 p.p.m., suspended solids 41 p.p.m. (including 28 p.p.m. volatile suspended solids), dissolved solids 369 p.p.m. (including 155 p.p.m. volatile dissolved solids), total solids 410 p.p.m., total ash 227 p.p.m., total volatile solids 183 p.p.m., organic carbon 56 p.p.m., organic hydrogen 16.6 p.p.m., organic nitrogen 17 p.p.m., ammonia nitrogen 14 p.p.m., nitrate nitrogen 1 p.p.m., Ca. 9.5 p.p.m., Mg 6.5 p.p.m., P 4.1 p.p.m., K 11.8 p.p.m., and Na 71.5 p.p.m.

* This synthetic sewage was prepared as described by Weinberger (6). After sterilization at 115° C. for 20 min. in sealed containers, it has these characteristics: pH 9.5, total alkalinity 160 p.p.m., bicarbonate alkalinity 117 p.p.m., manometric B.O.D. (5-day, 25° C.) 165 p.p.m., suspended solids 175 p.p.m. (including 147 p.p.m. volatile suspended solids), dissolved solids 377 p.p.m. (including 130 p.p.m. volatile dissolved solids), total solids 552 p.p.m., total ash 107 p.p.m.,

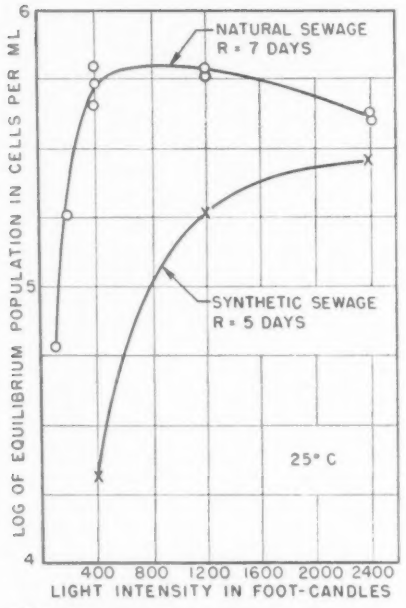

FIGURE 4.—Effect of light intensity on algal population.

5 days. The resulting environment furnished the algae with more abundant nutrients, but subjected them to a shorter period of lighting.

Populations and Yields

Effect of light intensity on population of *E. gracilis* is shown in Figure 4. From 100 to 400 ft.-c., the population in the natural sewage (upper curve) increases to a maximum at or near 400 ft.-c. From 1,200 to 2,400 ft.-c. the population falls off slightly. The lower curve shows similar data obtained with the relatively strong synthetic sewage. The lower curve indicates that the *Euglena* did not develop as well as with the greater amounts of the stronger nutrient, except at a high light intensity. The yields of algae produced each day are shown in Figure 5. Both curves follow the trends of the comparable population curves in Figure 4.

There was no systematic variation in the morphology of *Euglena* with varying light intensities. From 90 to 95 per cent of the cells remained motile, as was the case in earlier studies (3). Great variations in the size of cells, perhaps resulting in variation in yield, are noted at all light intensities; however, cells produced at low light intensities tend to be larger than those from highly illuminated cultures.

Bacterial populations attained a maximum at 10^8 c.p.ml. (colonies per ml.) at 100 ft.-c. The minimum, 10^6 c.p.ml., occurred at 2,400 ft.-c. Intermediate populations were obtained at intermediate light intensities, but without consistent variation.

Chlorophyll Production

Figure 6 shows the variation of chlorophyll content per million algal cells as a function of light intensity. Chlorophyll per cell is low in the range where highest yield is obtained, 400 to 1,200 ft.-c. The decrease in chlorophyll is very rapid in the range from 100 to 400 ft.-c., indicating that there is no direct relationship between chlorophyll content and yield under varying

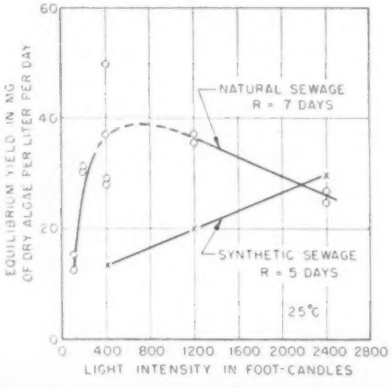

FIGURE 5.—Effect of light intensity on algal yield.

total volatile solids 445 p.p.m., organic carbon 112 p.p.m., organic hydrogen 20 p.p.m., organic nitrogen 28 p.p.m., ammonia nitrogen 14 p.p.m., nitrate nitrogen 0 p.p.m., Ca 18.6 p.p.m., Mg 8.5 p.p.m., P 5.5 p.p.m., K 3.7 p.p.m., and Na 66 p.p.m.

light intensity. Photo-bleaching may explain the slower rate of chlorophyll decrease beyond 400 ft.-c. The measured chlorophyll values for cultures in the natural sewage indicate a slight increase in the range from 1,200 to 2,400 ft.-c., but these measurements may be in error since the macroscopic observations showed increased yellowing through this range.

A study of the components of the chlorophyll (that is, chlorophyll A and chlorophyll B) showed from 90 to 95 per cent chlorophyll A at all light intensities when the natural sewage was employed. With synthetic sewage, at $R = 5$, however, chlorophyll A averaged only 60 per cent. Strain (7) suggests that the ratio of chlorophyll A to B is indicative of the character of the nutritional environment, pointing out that higher ratios of B to A result when conditions are more favorable to chlorophyll formation.

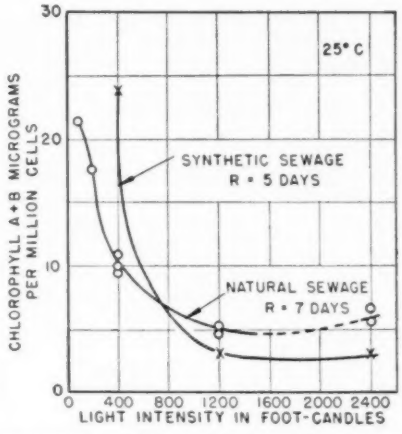

FIGURE 6.—Effect of light on chlorophyll production.

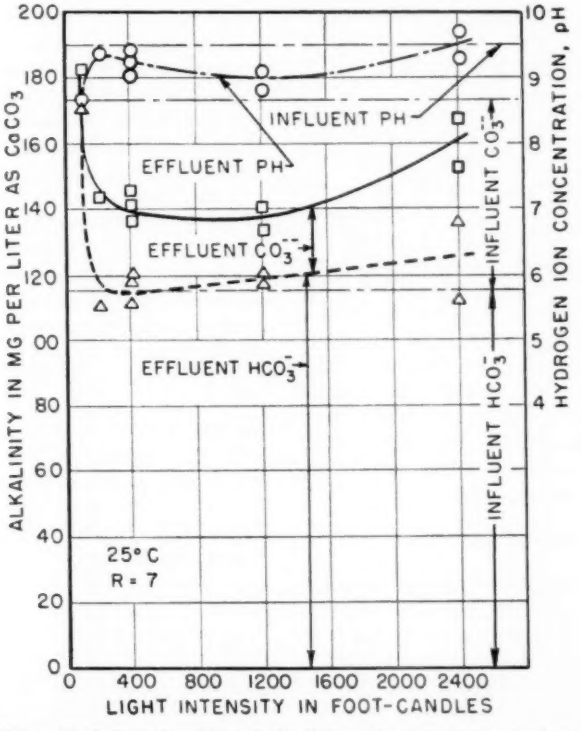

FIGURE 7.—Variations in pH and alkalinity with varying light intensities.

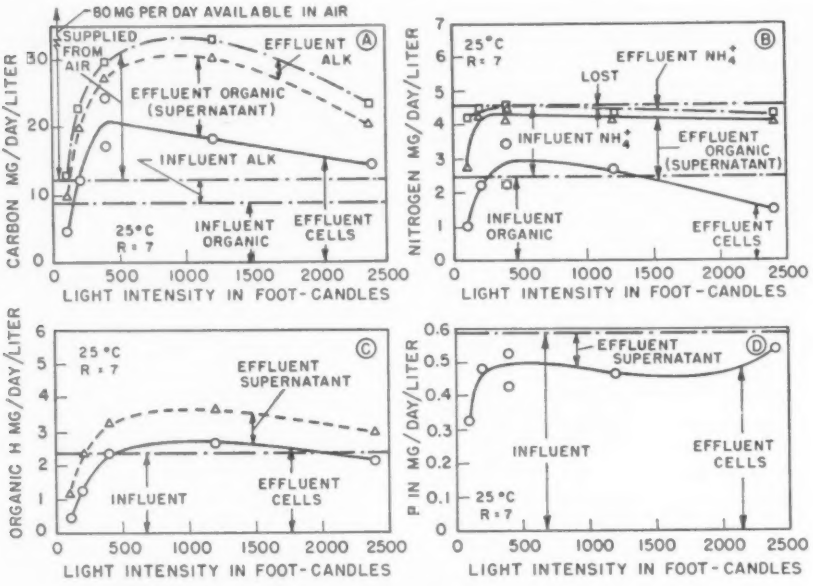

FIGURE 8.—Materials balances for algae cultured in sewage.

Character of Whole Effluents

Carbon—Figure 7 shows the results of pH and alkalinity data as a function of light intensity. From these curves it can be seen that *E. gracilis* consistently reduces pH, checking results previously reported (3). Probably the algae exchange H^+ ions for NH_4^+ ions. As shown by Figure 8A, which illustrates the carbon balance at equilibrium conditions, at all light intensities greater than 100 ft.-c. the total effluent carbon exceeds the total carbon contained in the influent sewage. The difference must be attributed to carbon supplied from the bubbling air, in accordance with the reaction

$$HCO_3 \rightarrow CO_2 + OH^-.$$

This reaction does not change the alkalinity of the system, but does increase the pH. Evidently, however, the production of acid already noted is sufficient to neutralize any OH formed and also to reduce the alkalinity initially present. In the process the HCO_3^- concentration is increased at the expense of $CO_3^=$. The net changes in pH, HCO_3 and CO_3 in any system depend upon the relationship between acid production and CO_2 absorption.

A large portion of the carbon utilized by the algae is not incorporated into the cells. As shown by Figure 8A, much of this carbon appears in the effluent supernatant, perhaps as a highly oxidized excretory product of the *Euglena*.

Nitrogen—Figure 8B shows there is very little loss of total nitrogen in the system in spite of the high influent pH. The small residual ammonia in the effluent indicates that the principal source of nitrogen for *Euglena* is NH_4^+. The large amount of effluent organic nitrogen in the supernatant may again be an indication of some excretory product by *Euglena*.

Hydrogen, Phosphorus, and Other Ions—The synthesis of an excretory product by *Euglena* is further indicated by the relatively large amount of organic hydrogen in the supernatant

(Figure 8C). Total effluent organic hydrogen exceeds total influent organic hydrogen, presumably because of photochemical decomposition of water. The phosphorus balance shown in Figure 8D indicates that this element may have been a limiting nutritional factor at the higher light intensities. Similar balances (not shown) for magnesium, potassium, and calcium show that these elements were not limiting to growth. More calcium was taken up by the *Euglena* cells at low light intensities than at high light intensities.

Oxygen Production

A basic problem in studying photosynthetic oxygenation is the determination of the oxygen produced. In earlier studies the oxygen-producing capacities of the algae were directly measured by transferring them to the Warburg apparatus. However, the environment in the Warburg flask, including light intensity, is different than in the growth units. For this reason, in the present studies the oxygen production has been calculated utilizing the method introduced by Myers (8). This method employs the analyses of the algal cells to determine the "assimilatory quotient." As an example, an analysis of *Euglena* may show 59.3 per cent C, 5.24 per cent H, 26.3 per cent O, and 9.1 per cent N on an ash-free dry-weight basis. Division by the atomic weights of these elements converts these percentages to the formula

$$C_{7.62}H_{8.08}O_{2.53}N_{1.0}.$$

All evidence indicating that ammonia is the source of nitrogen, it may be assumed that the synthesis of this material follows the equation

$$1.0\ NH_4^+ + 7.62\ CO_2 + 2.53\ H_2O \rightarrow$$
$$C_{7.62}H_{8.08}O_{2.53}N_{1.0} + 7.62\ O_2 + 1.0\ H^+.$$

The assimilatory quotient A_q then is

$$CO_2/O_2 = \frac{7.62}{7.62} = -1.00.$$

These values have been determined for all light intensities investigated, and the results (Figure 9) show that oxygen yield per cell increases with intensity up to about 1,200 ft.-c. A numerically low assimilatory quotient corresponds to a high oxygen yield.

If the total daily carbon yield is known, the assimilatory quotient can then be used to calculate total oxygen yield by the formula

$$\frac{O_2}{C} \times \frac{1}{A_q} \times Y_C = Y_{O_2},$$

where O_2 and C are respective molecular weights, A_q is the assimilatory quotient and Y_C and Y_{O_2} are the yields of carbon and oxygen, respectively.

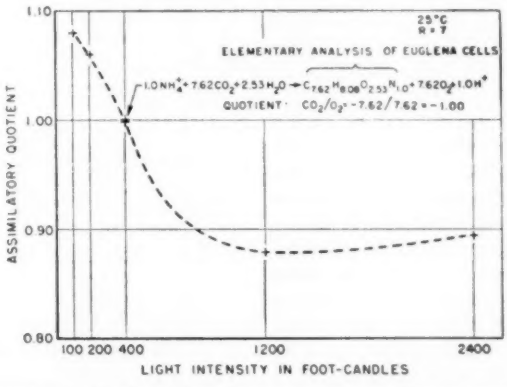

FIGURE 9.—Effect of light intensity on assimilatory quotient.

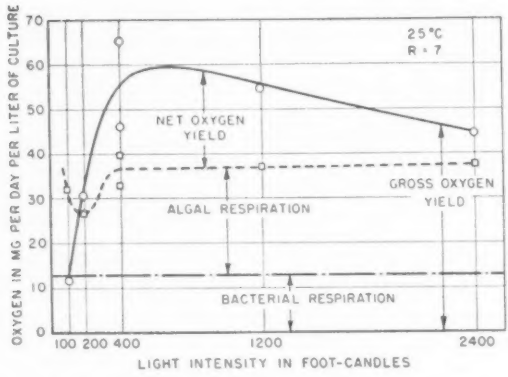

FIGURE 10.—Effect of light intensity on oxygen production.

These calculated gross oxygen yields are plotted in Figure 10. Maximum gross yield occurs in the range from 400 to 1,200 ft.-c.

The oxygen consumed by the algae cells in the absence of light was measured with the Warburg respirometer. The bacterial respiration demand at equilibrium was assumed to be approximately B.O.D./R, where B.O.D. is the 5-day, 25° C., Warburg B.O.D. of the influent sewage and R is the retention period in days. By plotting these data with ordinates superimposed, the net oxygen yield is obtained (Figure 10).

The relatively high respiratory requirement of *Euglena* at 100 ft.-c. is indicative that little, if any, oxygen was produced at this low light intensity. *Euglena* are capable of growing saprophytically in the dark, a phenomenon commonly reported in the literature.

A comparison of the oxygen curve in Figure 10 and the cell yield curve in Figure 5 shows that maximum yield and maximum oxygen production coincide, at approximately 700 ft.-c.

As in the earlier studies (1) (3), the cell-free supernatants from continuous cultures grown under varying light intensities show consistently low values of B.O.D. These values ranged from 25 p.p.m. at 100 ft.-c. to approximately 10 p.p.m. at 2,400 ft.-c. Chemical analyses of the supernatant material (see Figure 8) show appreciable amounts of carbon, hydrogen, and nitrogen.

Composition of Algal Cell Material

As light intensity increases from 100 to 400 ft.-c., retention period being constant, large variations are found in

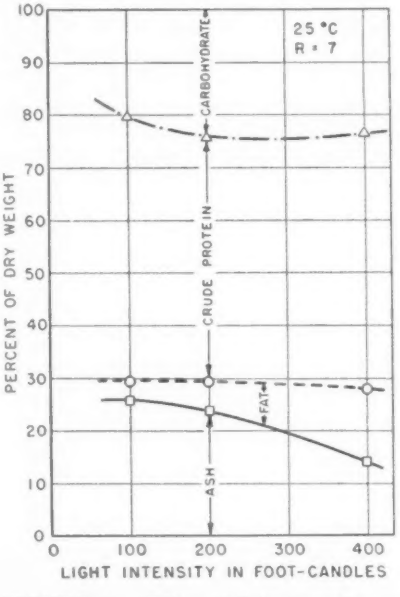

FIGURE 11.—Effect of light intensity on composition of algae.

the chemical composition of *E. gracilis* (Figure 11). Higher nitrogen content at lower light intensity might be attributed to the increased amount of chlorophyll contained in the individual cells. However, less total chlorophyll is formed at 100 ft.-c. than at intensities exceeding 100 ft.-c., because of the fewer cells present. More carbohydrate per cell is synthesized at higher light intensities, the maximum of carbon being contained in cells illuminated from 200 to 400 ft.-c. Ash content of the cells is at maximum, and hydrogen content at a minimum at 100 ft.-c.

Figure 11 shows that carbohydrate and fat tend to increase with increased light intensity, and that protein and ash tend to decrease. *Euglena* grown near optimum light intensities and at short retention periods may contain up to 50 per cent crude protein.

Effect of Temperature

In preliminary temperature studies to be reported later, the data indicate that algal population, chlorophyll content, assimilatory quotient, age of cells, and uptake of inorganic ions are comparatively independent of temperature near optimum temperature. However, the growth of bacteria, yield of algal cell material and oxygen, over-all sewage treatment accomplished, and uptake of organic ions may be appreciably influenced by slight changes of temperature. Jahn (11) has shown that the optimum temperature for *E. gracilis* when grown in acetate media in the dark is near 23° C.

Summary and Conclusions

In the laboratory, green algae have been employed to effect secondary sewage treatment through photosynthetic oxygenation. The physical and chemical environments act to determine the yield of algal cells and of oxygen. Under optimum conditions the algae cells remain young; that is, they are maintained in the logarithmic phase of reproduction. Such cells have relatively high concentrations of chlorophyll and of protein, and low concentrations of carbohydrates and fats. Both algae yield and oxygen production are high, and the oxygen production exceeds the demands of all living organisms in the system.

Previous studies showed that, assuming favorable physical conditions, the availability of carbon is generally the limiting factor determining the yield of algae. As the loading rate decreases, and carbon becomes more limiting, cells are unable to multiply or multiply at a greatly decreased rate. Many of the cells become "old"; that is, they store up carbohydrates and fat from the limited amounts of carbon available. They contain lower percentages of chlorophyll, the yield of algae is reduced, and the oxygen produced may be less than the total demands.

The present studies show that optimum light intensity for the algal species *E. gracilis* depends upon such variables as strength of sewage and the retention period. For a natural sewage having a B.O.D. of 90 p.p.m. (Warburg, 5-day, 25° C.), the optimum light intensity is from 400 to 1,200 ft.-c. When light intensity increases beyond optimum, the cells undergo a transition from "young" to "old," which is somewhat comparable to that produced by a decreasing loading rate—that is, by a shortage in nutrients resulting from long retention periods. In both environments (constant light with varying retention period, or constant retention period with varying light intensity), the algal cells are subjected to comparable total light exposures; that is, the total exposure may be the principal factor determining the average cell "age," hence the yields of both algae and oxygen. For example, a low loading rate (long retention period) at a low lighting intensity can effect the same total exposure as a high lighting intensity at short retention periods. In natural bodies of wa-

ter, algae suffering from a shortage of nutrients take longer to reproduce. In becoming "older" they suffer prolonged exposure. High-intensity exposure could produce similar results, even when nutrients are abundant.

Light is both essential and inimical to photosynthetic oxygenation because of its effects on chlorophyll. It is essential to formation of chlorophyll, which in turn, under the influence of light, decomposes water, producing the hydrogen necessary to photosynthesis and, as an incidental result, the desired oxygen. However, the light intensity, the longer the period of exposure, and the greater the amount of chlorophyll present, the greater will be the rate at which the chlorophyll is broken down.

As light intensity becomes excessive, the rate of breakdown of chlorophyll approaches the rate of chlorophyll synthesis, resulting not only in bleaching and yellowing, but in reduced hydrogen supply and hence reduced photosynthesis. Reduced photosynthesis results, in turn, in a slower rate of multiplication and hence in "aging" of the cells. These results all tend to indicate that a period of intensive light followed by a dark period is beneficial if not vital to increasing the over-all rate of photosynthesis.

Variations in temperature appear to be principally important in their influence on rate of cell growth subsequent to initial photosynthesis, and hence upon total cell yield.

In summary, rates of cell multiplication, cell yield (including oxygen yield), chlorophyll synthesis, chlorophyll breakdown, and photochemical decomposition of water by chlorophyll may be considered as interdependent variables. Their particular interaction depends upon the physical and chemical environmental factors, especially availability of nutrients, light intensity, and temperature.

In actual oxidation ponds, all of these factors vary between wide limits every day. Moreover, at any given moment they are different at different places along the pond traverse. Because the algae are "ecologically versatile," they are able to adapt themselves to these changing conditions. However, if it proves feasible to control the environment of oxidation ponds to minimize unfavorable conditions, the efficiency of such ponds should be greatly improved.

Studies are under way, both in the laboratory and in a pilot-scale outdoor pond, to study the effects of light periodicity and of varying temperature. These will supplement the present work on light intensity and the earlier work, which investigated the nutritional factors.

Acknowledgments

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INDUSTRIAL ALCOHOL FROM SPENT SULFITE LIQUOR

The manufacture of alcohol from wood pulp and paper waste materials was described at the recent joint conference of the American Institute of Chemical Engineers and the Chemical Engineering Division of the Chemical Institute of Canada, held in Toronto, Canada.

In the paper "Improvements in the Manufacture of Industrial Alcohol from Sulfite Waste Liquor during the Last Ten Years," H. G. Joseph, who has been in charge of the Thorold alcohol plant of the Ontario Paper Co. since it started, describes the steps by which ethyl alcohol is made.

About 10 years ago, there was a pressing need for alcohol to fulfil the demands of the synthetic rubber and munitions industries in Canada and the United States. Due to shipping shortage, the supply of molasses from the West Indies and Cuba had been cut off, thereby depriving the industrial alcohol manufacturers of their principal raw material. About that time the Ontario Paper Co. constructed a plant at Thorold, Ont., to make industrial alcohol out of the spent sulfite liquor from the mill at that location.

This was the first plant of its kind in Canada, although the process had been operated in Europe for about 40 years. The plant started operations in May, 1943, and was soon making a substantial contribution to the wartime alcohol requirement. Following the cancellation of war-time contracts, a higher quality alcohol was required in order to compete successfully in industrial markets. The means by which this was accomplished are described at some length in the paper.

Only a very small fraction of the sugars now being poured into the rivers of the United States and Canada is being economically employed. It is estimated that Canadian mills throw away each year about 250,000 tons of sugar, from which about 28,000,000 gal. (Imp.) of ethyl alcohol could be produced. This quantity is far in excess of present requirements, but it illustrates the potential raw material supply available.

Industrial Wastes

1952 INDUSTRIAL WASTES FORUM *

R. W. HESS, *Leader*

Head of Pollution Research, Chemical Aniline Division, Allied Chemical and Dye Corp., Buffalo, N. Y.

Chairman Hess:—The program committee has selected for discussion at this forum what are regarded as timely topics on which considerable progress is being made and on which much more knowledge is needed in the interest of accelerating the abatement and prevention of water pollution by industrial wastes. These subjects are: flotation, skimming, subsurface disposal, lagooning with sodium nitrate, anaerobic digestion, and high-rate filters.

Flotation

As applied to waste liquors, flotation is a method for converting suspended substances, and some colloidal, emulsified, and dissolved substances, to floating matter. Aeration seems to be the basic element. However, since mechanical aids are required for removing floating matter and since chemical aids are sometimes helpful in converting colloidal, emulsified, and dissolved substances to suspended matter, this method sometimes involves other methods of treatment of chemical and mechanical types. These other methods include skimming, which is the basic element of the next topic, as applied especially to separation of oil from waste liquors.

Flotation for separation of valuable minerals, particularly copper sulfide, from pulverized ores is a long-established practice. The problem in that practice, however, is considerably different from that for wastes, in that it involves separation of one component from a much larger proportion of another. The basic principle in mineral flotation is that the heavier metal is floated by coating with a chemical which, by prevention of wetting, causes accumulation at the surface, where it is removed in the froth. Frothing is induced by aeration and use of a frothing agent, such as pine oil.

Application of flotation to wastes is relatively new. The principles and practices in this field appear to be somewhat different.

F. S. Gibbs, President, F. S. Gibbs, Inc., Newton Lower Falls, Mass.:—The term "flotation" includes both violently agitated froth flotation, as used in the separation of ores in the mining industry, and quiescent flotation, which is now earning its way in industrial waste treatment as an exceptionally efficient method for the removal of most suspensions from waste waters.

The clarification and purification of industrial wastes usually involves the removal of suspensions in the waste waters or the precipitation and subsequent removal of dissolved solids. Despite the fact that many of the present or created suspensions in these wastes will not or cannot efficiently be made to settle, settling types of clarification equipment are stubbornly installed. In many, and possibly all of these cases, quiescent flotation equipment would do a superior job in clarifying and purifying the waste water.

No claim is made that quiescent

* From transcript, 25th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; New York, N. Y.; October 6–9, 1952.

flotation is a panacea for all industrial wastes ills. Many industrial wastes can only be treated by biological processes. There are some cases wherein the conventional types of settling equipment will do a job that cannot be done efficiently and economically by flotation. There are other industrial wastes that can best be clarified and purified by a combination of settling and flotation; settling first to remove the heavier suspensions and following with flotation for the removal of the remaining lighter suspensions.

There are, of course, many other industrial wastes that can best be clarified and purified with flotation alone. A specific waste should be studied to determine the method or methods best suited for accomplishing the desired results. Quiescent flotation should never be discounted as a valuable wastes treatment tool, and its abilities should be analyzed carefully before final decisions are made.

Flotation has been slow to earn acceptance in industrial wastes treatment. In addition to the natural tendency of engineers to resist progress, there has been the tendency of manufacturers of settling clarification equipment to disparage flotation equipment in their advertising in the hope of influencing engineers and industrial officials in favor of settling equipment designs, regardless of the type of solids to be removed. Many consulting and industrial engineers have been so thoroughly convinced that they will employ special chemical applications, literally hanging "sash weights" on liquid suspensions, so that settling equipment can be made to work.

Fortunately, some industries have recognized their wastes treatment problems for what they really are; problems for which suspensions settling equipment cannot and does not live up to its advertising claims; problems that definitely need a new approach and design for their solution. These industries have turned to quiescent flotation and have been rewarded with the achievement of efficient, dependable, and economical clarification and purification of the wastes with relatively low requirements for capital expenditure. These alert industries can take the credit for today's development of quiescent flotation and its excellent application to many, many problems of clarification and purification.

A detailed discussion of the mechanics of quiescent flotation is beyond the scope of this Forum. Actually, quiescent flotation involves a simple and rather obvious handling of liquid suspensions. Suspensions that settle slowly or that remain suspended can be agglomerated and buoyed to the liquid surface quickly and thoroughly by the lifting power of tiny air bubbles attaching themselves to the suspension particles.

It is characteristic of quiescent flotation that floated suspensions are readily removed continuously from the liquid surface, and the skimmings are collected as a concentrated sludge.

Another valuable characteristic of the floated sludge is its free-draining property. The sludge contains the tiny air bubbles that rafted the suspension particles to the surface. These air bubbles serve to aid in further water removal or concentration of sludge. In many cases the sludge from a quiescent flotation unit is held in a receiving tank for 1 or 2 hr. and then clear water is drained from the tank bottom, often increasing the solids content of the sludge remaining by 100 to 200 per cent. The commercial value in producing a sludge which will concentrate by itself is of considerable importance.

Quiescent flotation has another characteristic that is of great value in wastes treatment. The tens of billions of tiny air bubbles that are constantly moving upward in the liquid provide an unusually intimate contact for oxygen with the liquid and the suspensions. As a result, the immediate

chemical oxygen requirement of the waste is no longer immediate, but is usually satisfied. The effluent water from quiescent flotation usually contains quantities of dissolved oxygen, often to the point of saturation. The sludge from the flotation unit is stabilized and the quiescent flotation unit is free from objectionable odors in its operation. Air-induced quiescent flotation is probably the first treatment process to make efficient use of atmospheric oxygen.

Another important feature of flotation clarification is the rapidity with which suspensions can be floated by the use of the tiny air bubbles. A conventional "high-rate" settling unit of the sludge blanket type might require a minimum retention of 2 hr. for a particular waste. The same waste, and probably with the same or less expensive coagulating chemical application, would be clarified equally well and probably a great deal better by quiescent flotation in a total retention period of about 20 min.

The saving in capital cost of equipment is obvious. The flotation equipment structure required would be less than one-sixth of that required by "high-rate" settling equipment, and proportionally less floor or ground area is needed for the installation. Most industries today are cramped for space and the compactness of flotation wastes treatment equipment makes it most attractive.

The ratio of high-flow capacity to unit size, a ratio that is enjoyed only by flotation equipment, enables the treatment plant designer to create an unusually flexible plant layout at minimum cost. The flotation equipment avoids the bulk of the field construction and all field fabrication costs. A 300-sq. ft. flotation unit, with a capacity of as high as 1,200 g.p.m. on most applications, can be entirely shop fabricated and shipped as a complete unit. The unit requires only one simple rectangular foundation at ground or floor level, eliminating costly excavation. If a particular industrial waste flow is in excess of the capacity of a single 300-sq. ft. unit, one or more complete additional units, as required to handle the maximum flow rate, are added in parallel, providing unusual flexibility in plant operation.

Most commercial installations of flotation equipment do not require separate coagulation retention. A coagulation reaction and agglomeration, requiring 30- or 40-min. retention prior to settling clarification, can often be accomplished in the flotation unit in one-tenth of the time.

Quiescent flotation clarification is now providing many different industries with efficient and economical wastes treatment. The applications cover a broad range of wastes types, from simple oil or grease removal to the clarification of wash water from foundry sand reclaiming systems. The programs for eliminating stream pollution and the efforts of industries to recover lost values from their wastes are both being served well by flotation equipment and methods.

Robert A. Baum, Executive Vice-President, Bulkley, Dunton Processes, Inc., New York, N. Y.:—Flotation of suspended solids by means of mechanically entrained air or gases has been commonly employed for many years in the selective flotation of minerals. Adaptations of such systems previously had limited application to a variety of industrial wastes and other solids. In these cases the flotation principle involves diffusion of small air bubbles in the liquid containing the solids, followed by the attachment of the air bubble to or around the particle to be floated. This process may be aided by flocculents or surface-active agents, respectively.

Opposed to entrained air or gas flotation, a system whereby the air is truly dissolved in the liquid carrying the suspended solids has been widely used

TABLE I.—Typical Efficiencies of Dissolved Gas Flotation Treatment of Wastes

Waste Type	Sus. Sol. in Influent (p.p.m.)	Reduction Obtained (%)	B.O.D. in Influent (p.p.m.)	Reduction Obtained (%)
Petroleum production	441	95.0	—	—
Railroad maintenance	500	95.0	—	—
Meat packing	1,400	85.6	1,225	67.3
Paper manufacture	1,180	97.5	210	62.6
Vegetable oil processing	890	94.8	3,048	91.6
Fruit and vegetable canning	1,350	80.0	790	60.0
Soap manufacture	392	91.5	309	91.6
Cesspool pumpings	6,448	96.2	3,399	87.0
Primary sewage treatment	252	69.0	325	49.2
Glue manufacture	542	94.3	1,822	91.8

by the paper industry during recent years to attain highly efficient removal of fibrous and filler materials, such as clays, from white water. The latter system within the last 10 years has given indications of being highly effective in flotation of the wide miscellany of suspended solids and oils and greases found in industrial and municipal waste. As such, flotation is rapidly becoming a proven and successful new method of solids separation now available to the industrial and sanitary engineer, capable of being evaluated in comparison with previously available means, such as sedimentation, filtration, centrifuging, and allied methods.

In dissolved gas flotation, injected air is placed in true solution in the liquid flow by increasing the entire liquid pressure in a continuous-flow retention tank to a pressure that gives the desired amount of air or gas in true solution. The flow is then released to atmospheric pressure in an open flotation cell and the gases coming out of solution are immediately adjacent to or upon or within the solid to be floated. In this manner the dissolved gas principle eliminates the mathematical probability or the high chemical usage approach to an isoelectric point needed in entrained air methods to assure a bubble per particle.

In general, dissolved gas flotation may be applied to efficient solids-liquid separation of not only those materials of a specific gravity close to 1.0, but also of materials of substantially high specific gravity as long as such materials are in a small-particle state. Inasmuch as materials in a large-particle state may be settled or screened for prior removal, there are few limitations on the materials that may be floated economically.

After flotation the blanket of solids is conventionally skimmed off and clarified liquid is removed from the bottom of the flotation cell.

Dissolved gas flotation offers the advantages of positive control of process, low space requirements, avoiding bacterial decomposition of valuable byproducts, and substantially more concentrated sludge due to elimination of the liquid head over the sludge blanket, as is found in a converse or sedimentation system. Table I gives some typical results obtained in various industries utilizing dissolved gas flotation for wastes treatment.

Generally, industry seems to prefer the use of flocculents or flotation aids as long as they are economical. In a municipal application that may not necessarily be true. Therefore, some of the industrial uses mentioned not only utilize the efficiency of dissolved gas, as has been pointed out earlier, but also utilize flocculating chemicals.

For example, in petroleum production, where waste oils are suspended either in brine or in water, a typical

installation with 441 p.p.m. suspended solids can obtain 95 per cent solids reduction within an 18- to 20-min. flotation time with the use of such conventional chemicals, for example, as ammonium sulfate and activated silicon. In such cases emulsions are broken and high efficiency is attained in floating materials that in a conventional sedimentation system would stay suspended in the middle and neither sink nor float and, as a result, represent a loss of efficiency.

Meat packing is one of the applications that should be qualified. If the problem is strictly one of remedying pollution, auxiliary chemicals can be used to help reduce the B.O.D. and attain a very high efficiency. If recovery of the oils and greases is necessary, then the degree to which chemicals can be used is dependent upon how well a valuable by-product can be recovered. Taking a pollution situation in meat-packing wastes, a waste containing 1,400 p.p.m. suspended solids can be reduced by 85 per cent, provided a re-use of the flocculated material is not desired. If it is desired, it is conceivable that 70 per cent recovery can be attained.

In cesspool collection, which of course is a great deal different from primary sewage treatment, some recent figures on wastes having 6,448 p.p.m. suspended solids show 96 per cent suspended solids reduction. In this case, of course, the use of chemicals is justified economically.

In primary sewage treatment, recent tests show 252 p.p.m. suspended solids reduced by 69 per cent without the use of chemicals. That is attained with air or dissolved gas only. Just as a matter of interest, there is such a plant operating on a pilot-plant basis at Fall River, Mass.

Another application is glue manufacturing, which points out something that Mr. Gibbs mentioned earlier and that is very important in flotation systems; that is, if the B.O.D. is primarily in the suspended solids or colloidal dispersed solids phase, it is possible to get remarkable B.O.D. reductions with flotation. Glue manufacture fits that very situation closely, as do tanning and other industries where the materials are really colloidal and not in solution. In such a case, with, say, 542 p.p.m. suspended solids in the influent, it is possible to get 94 per cent solids reduction and 91 per cent B.O.D. reduction.

Of primary interest to sewage and industrial wastes users' evaluation of this new process would be cases of suspended solids separation to either replace or augment conventional sedimentation, and cases presenting a colloidal particle separation problem that does not economically merit rough filtration or fine filtration. Flotation does an excellent job in those positions.

Another usage for flotation is as a primary treatment in a fine filtration system. In the manufacture of antibiotics, where filtration is necessary, use of dissolved gas flotation ahead of filtration will economically relieve the filters by removing the heavy load cheaply. Subsequent filtration for secondary treatment is very economical.

Another use for dissolved gas flotation is in oil and grease separation where there is a high degree of emulsified dispersed fractions; also, of course, in primary sewage treatment.

The system bears investigation on activated sludge, where it is possible to attain a high degree of solids removal and saturation of the influent liquor with oxygen.

Question from the Floor:—What B.O.D. reduction can be expected from flotation in primary sewage treatment?

Dr. Baum:—A typical value would be that obtained at the Fall River, Mass., plant—namely, close to 40 per cent.

William A. Ryan, Consultant, New York State Canners Assn., Rochester, N. Y.:—This method has been used in a large canning plant in the west for

at least six months, but has not been very successful. With the large amount of suspended solids involved it failed miserably.

Dr. Baum:—Mr. Gibbs mentioned earlier that flotation is not a miracle machine, but is more efficient on some industrial wastes than on others. The measure of the efficiency of flotation in a canning wastes problem, for example, would be its efficiency when compared with a sedimentation system, assuming that screening does not get out the particular particles that you are after, a condition that prevails in typical canning operations.

Economic screening leaves a large number of suspended solids remaining. Fine or sharp filtration is obviously uneconomical. The choice is between sedimentation and flotation. So, answering the question, it is my opinion that in that case flotation is more efficient than sedimentation would be in an equivalent condition. That does not mean that that solves the entire problem. Of course, if biological treatment is needed that has to follow.

Question from the Floor:—Are there any figures available on grease separation from the domestic sewage operation?

Dr. Baum:—Testing is still going on at this particular location. However, oil and grease separation have been in excess of 50 per cent, and usually nearer 60 per cent.

Skimming

Chairman Hess:—After suspended matter has been brought to the surface of waste liquors by flotation or other means, the next step is separation from the liquor. Although the procedure selected for discussion is skimming, as applied especially to the petroleum industry, the practice involves much more than is indicated by the topic. In fact, it would seem that collection of the material on the surface is the primary problem, for the solution of which attention is being given to methods in addition to flotation.

Another procedure frequently associated with skimming is separation and disposal of bottom sludge. This also has its problems.

R. J. Austin, Research Dept., Standard Oil Company (Indiana), Whiting, Ind.:—The problem of separating oil from water is an old one in the petroleum industry and was one of the first to be considered by the American Petroleum Institute's Committee on Disposal of Refinery Wastes when it was organized in 1928. Although the basic elements of the problem were the same then as now, more efficient separation has become necessary and the difficulties attending its attainment have become greater. An ever-expanding industry and population, making heavy demands upon water resources, and the increased complexities of refining processes have accentuated the necessity for continued attention by the refining industry to the problem of oil-water separation. The problem is also of growing concern to other industries.

The water requirement for refining a gallon of crude oil averages 17 gal., the extremes ranging from about 7 to 30. It is beyond the scope of these remarks to explain this variation. The economics of refinery water usage are well appreciated, and water consumption is generally based on practical operating principles.

The major portion of the water used in a refinery is for cooling by indirect heat exchange, the water never coming in contact with oil except in the event of equipment leakage. This spent cooling water leaves the refinery unchanged except for a temperature increase.

A minor portion—10 to 20 per cent of the total volume of water pumped to the refinery—actually comes in contact with oil in the operation of such equipment as washers, stills, jet condensers, and contact coolers. This used process water is the principal contributor to the problem of oil-water

separation. Typically, the oil content of this water is less than 1 per cent when not diluted by spent cooling water.

The total amount of oil that gets into a refinery sewer system may range as high as 3 per cent of the volume of crude oil processed in the refinery, but the average is probably about 2 per cent. Humble Oil and Refining Co. has recently reported * that oil in the sewer system at its Baytown, Tex., plant has been reduced to 0.3 per cent of the refinery crude run.

A refinery oil-water separator has a job somewhat similar to that of the primary settling tank employed in the treatment of sanitary sewage. The influent to an oil-water separator may contain the following:

1. Free-floating oil, which is readily separable.
2. Dispersed oil, most of which coalesces rapidly and becomes readily separable.
3. Dissolved oil, which cannot be separated but is present in insignificant amount.
4. Emulsified oil, which coalesces slowly and may or may not separate in a reasonable length of time.

Fundamentally, oil-water separators are designed on the basis that the influent is composed of water and dispersed oil only. This condition seldom exists in actual practice. Furthermore, the performance of an oil-water separator is influenced by other factors than the oil content of the influent. In addition to oil, there are usually solids present that may be derived from silt in the intake water, surface drainage, or reaction of salts initially present with chemicals used in refining operations.

Considerable attention by refinery personnel is necessary to minimize entry of oil to the sewers and of waste materials that would result in emulsification of oil or act as emulsion stabilizers. The character of the separator influent is evaluated by an empirical test commonly referred to as the Susceptibility to Separation, or STS, test. This test is similar to the well-known Imhoff cone test in that a sample of the waste is allowed to remain quiescent and the oil content of the clarified liquid is determined. The STS test indicates the amount of oil that cannot be separated by gravity. Because the test conditions are more favorable to separation than those actually existing in any separator, the effluent oil content will be somewhat greater than the STS number. Once a background of data is established for a particular installation, the normal range of difference between effluent oil content and STS number, or the variation in ratio of these two values, may be used to determine whether a high oil content in a separator effluent is the result of the character of the influent or of malfunctioning of the separator.

The elements of an API oil-water separator are essentially the same as those of the rectangular settlers used in domestic sewage treatment practice —a sedimentation basin with devices for obtaining the best possible flow distribution and for removing surface and bottom accumulations. Considerable study has been given to the subject of separator design by the American Petroleum Institute's Committtee on the Disposal of Refinery Wastes. The most recent investigation made is the API-sponsored research program at the University of Wisconsin.* As a result of this program, several important rec-

* Resen, F. L., "How to Reduce Oil Losses in a Refinery." *Oil Gas Jour.*, **51**, No. 11 (July 21, 1952).

* "Investigation of the Behavior of Oil-Water Mixtures in Separators." Univ. of Wisconsin Eng. Exper. Sta., Hydraulic and Sanitary Eng. Laboratories. Final Report (Aug., 1951); also, Rohlich, G. A., "Performance of a Gravity-Type Oil-Water Separatory on Petroleum Refinery Wastes—Discussion." THIS JOURNAL, **23**, 3, 291 (Mar., 1951).

ommendations are being considered. These recommendations are concerned with design of the inlet end, oil-particle size used as the basis for calculating rate of rise of oil, maximum allowable horizontal velocity, and the question of single-stage *versus* two-stage separators.

Although present-day separators perform satisfactorily, one serious operating problem remaining is the handling of separator sludge. Pumping the sludge from the separator is too frequently attended by suction-line blockage, and abrasion of pumps results in appreciable maintenance cost. The solids content of the sludge is low—about 2 per cent or less—and disposition of the sludge requires dewatering if it is to be used for fuel or possibly de-oiling if it is to be used as land fill.

Another problem of economic importance to refiners is the loss of oil by evaporation from the surface of the separator. Some refiners have met this problem by the use of covered or enclosed separators; others claim that covered separators are a hazard and prefer to accept the evaporation loss rather than risk the chances of explosion and fire.

In petroleum refineries, oil-water separators are essential process units designed and engineered in the same manner as any other processing unit. A separator is an integral part of the refinery, and its operation, performance, and economic aspects are viewed with the same critical attitude as those of other refinery equipment. Outside of the petroleum industry, there is a tendency to consider operation of separators highly profitable, and to assume that liberal expenditures should be allowed for the purpose of effecting 100 per cent oil removal. Two facts should help to clarify this misconception. First, 70 to 80 per cent of the removed oil is recovered in the approach or inlet channels before the waste water enters the separator proper; oil recovered in such channels cannot properly be credited to the separator. Second, oil particles having diameters less than 0.015 cm. are not amenable to separation from water by gravity differential. This limitation and the inevitable loss of some larger oil particles because of eddy currents make it economically unsound to strive for 100 per cent removal of oil by constructing separators having relatively great retention periods.

In other industries having similar problems of oil-water separation, the scale of the job is much smaller than that of the petroleum refiner, but the separation of the oil and water is often more difficult to accomplish. Patented equipment available from several manufacturers is adequate to meet many small-scale separation problems. Some of the more difficult situations may be handled by combined treatment methods, such as chemical flocculation and sedimentation, or chemical flocculation and air flotation, but these techniques become costly when carried out on a large scale.

C. H. Bunn, Jr., Standard Oil Development Co., Esso Eng. Dept., Linden, N. J.:—There are several practical points that merit further discussion, one of which is the question of covered separators. We do not like covered separators, in general, because it is difficult enough to secure proper operation of separating equipment when it is all wide open and can be seen and examined. Covered separators are also hazardous from the standpoint of fire and explosion.

The best method of overcoming those difficulties has been found to be what we call a "pre-separation" flume. It is very simple in its concept and construction, amounting to nothing more than expanding the cross-sectional area of the final collecting sewer, making it a channel of fair width. In an average case it might be 8 to 10 ft. wide. By this means the velocity in the channel is reduced sufficiently to give a surprising amount of separation. The best part of that separation is that a

good portion of the oil separated consists of the lighter, more volatile oils, or the ones that escape most easily if spread out on the broad surface of an open separator. Those can be recovered by simple floating and skimming equipment at the end of the covered pre-separation flume.

The next point to be watched is the transition section from the pre-separation flume into the separator proper. This should be as streamlined as possible to eliminate every possible source of re-mixing. We do that by using an open channel approach, designed as carefully as possible to eliminate obstructions and sharp corners and anything else that would create turbulence. The influent also enters the individual separator channels, usually arranged in parallel, with free, full openings; full as to width and full as to height. Provisions are made for shutting off one channel at a time to facilitate mechanical repairs. This is done by applying stainless steel temporary gates at the entrance to the channel when needed.

Attention to the little things in the way of hydraulics gives the best operation in a separator. In the separator proper, the sludge removal mechanism and the oil skimmer must be so designed as to create no turbulence in the settling basin. Several types of conventional equipment are available.

It must be remembered, moreover, that a separator is nothing but a piece of equipment that is operated by gravity; it is not a chemical treatment plant. Therefore, care must be exercised as to what is put into the sewers leading to the separator. Segregation of waste streams will help cure that situation to some degree, the amount of economical segregation into separate systems depending a good deal on the size of the plant. A small plant cannot afford to segregate and make two or more systems, whereas a large plant can. Sometimes the condition is based even on such characteristics as the specific gravity of the oil. Light oil will separate much more readily and does not need the same degree of efficiency in separating as the heavy oil.

By segregation and by education of operators within the plant not to consider the sewer system as the free dumping ground for something which should be re-cycled, or re-treated, or re-refined, a great deal of improvement can be obtained in separator operation.

Question from the Floor:—The API separator design usually includes an entrance device that carries the oil-water mixture down toward the bottom of the tank. Would it not be better to flow the mixture into the tank over a long weir in a narrow sheet, taking care that the flow is not turbulent, but streamlined, so that the oil starts near the surface where it is supposed to end up?

Mr. Bunn:—That question was very realistically answered by previously mentioned experiments conducted at the University of Wisconsin in tanks made of lucite so the investigators could see just what happened. The resulting recommendations include provision of open-channel approach to the separator channels and uniform flow distribution over the full cross-section.

J. Henry L. Giles, Assistant City Engineer, Meriden, Conn.:—Are the machine oils used in industry susceptible of separation by the means mentioned?

Mr. Austin:—They are not amenable to separation by gravity. Some kind of chemical treatment is required.

Question from the Floor:—Why are API separators built in two sections instead of one?

Mr. Bunn:—Older API publications showed a separator divided into a primary and a secondary chamber. The new manual coming out advocated a single chamber of equivalent length to the total of the two, thereby avoiding the turbulence in going from one chamber to the next.

The two-section separator was a compromise solution to the problem, resulting from the older practice of improving efficiency by using as many as 8 or 10 chambers in combination to reduce flow velocities or increase detention times.

Question from the Floor:—Has anyone ever tried the expedient of injecting oil bubbles into the oily waste to agglomerate the dispersed oil into big globules?

Mr. Austin:—There have been instances where light oils have been added to the influent of separators. It is true that this practice will increase the efficiency of the separator somewhat, but there also are quite a few disadvantages. Actually, the effluent from a separator contains only 50, 30, or 100 p.p.m. of oil. That is very little oil when reduced to gallons; it is hard to see about 50 gal. of oil in a million gallons of water.

Subsurface Disposal

Chairman Hess:—The next subject, subsurface disposal of waste liquors, suggests "sweeping the dirt under the bed." It is much more complicated than this, however.

First comes the question as to whether subsurface water supplies will be impaired. Geologists and sanitary engineers should have something to tell us about this. Sometimes it is necessary to treat wastes to make injection successful mechanically or to prevent impairment of water supplies. Engineers and chemists should have something to tell us about this. Even spraying of land, such as "woodland waste disposal" by Seabrook Farms, at Seabrook, N. J., might be regarded as a type of subsurface disposal.

N. J. Lusczynski, Hydraulic Engineer, Ground Water Branch, U. S. Geological Survey, Mineola, N. Y.:—It is the general policy of the U. S. Geological Survey to recommend against the underground disposal of sanitary and industrial wastes, because of the difficulty of obtaining adequate assurance in advance that a proposed disposal project will not contaminate currently or potentially usable aquifers, and because an aquifer, once contaminated, may be unusable for many years. It is recognized, however, that under certain conditions underground waste disposal may be safe, physically practicable, and economically desirable.

In planning the subsurface disposal of domestic sewage or industrial wastes, where there is intention to pump ground water subsequently for public supply, industrial, and other uses, the remarkable cleansing and disinfecting properties of sand, gravel, and silty-clay formations should be considered. Their ability under certain conditions to produce a water satisfactory as far as bacterial content is concerned is well-known, though perhaps not fully understood. Basically these properties must be presumed to be due to physical, chemical, and biological actions, reactions, and interactions.

There are countless examples of such purification of water; one of these is in Nassau and Suffolk Counties, Long Island, N. Y. For many years sewage, predominantly domestic, from more than 500,000 people, found its way to the underground formations after passing through cesspools, septic tanks, and leaching installations, or after primary or secondary treatment. The reuse of such water, after being mixed and diluted with a fresh supply underground and with percolating water from precipitation, was safe and satisfactory; that is true not only because of filtration in the very strict sense of the word, but perhaps more because of the inability of the harmful bacteria to survive in a changed environment, and because of absorption, adsorption, precipitation of insoluble substances, and perhaps ion exchange. Many of the pathogenic bacteria seem to die in the soil zone or in the zone of aeration. Those that survive to reach the water table do not move to any great depths

in the zone of saturation, but either move laterally a short distance in ribbonlike stringers, or are stranded to die as the water table recedes.

There is no question that sewage and wastes should not be introduced into consolidated formations, which have large openings and channels in the joints and along faults, through which contaminated and polluted liquids may pass, for the most part unchanged.

Unfortunately for subsurface disposal, the unconsolidated formations do not improve the quality or change the amount, to any marked extent, of most soluble organic and inorganic chemicals. As is well-known, passage of saline water through sand and gravel formations decreases the chloride content very little, if any. During World War II hexavalent chromium in a concentration as great as 40 p.p.m. traveled underground in the zone of saturation more than a mile down gradient from recharge basins into which it was dumped with acid wastes, after use for anodizing processes at aircraft plants on Long Island. The dimensions and concentrations of one such slug of contamination were defined. The chromium-contaminated water was found to be moving very slowly underground, much as would a submerged log or submarine in surface water, and apparently with little decrease in concentration. At present, chromic wastes at all aircraft plants on Long Island are pretreated to remove soluble chromium before disposal to recharge basins, to percolate eventually to the underground formations.

Nitrate, up to 15 p.p.m. as nitrogen, appears in water pumped from shallow public supply wells in Levittown, N. Y., a housing project built in a former agricultural area that was highly fertilized for potato growing. The results of occasional sampling suggest at this time that the nitrate is due locally much more, if not completely, to the leaching of the fertilizer, and less to the nitrogen content in the outflow from the thousands of individual cesspools and septic tanks. Records show very little change in the nitrate in the water from the shallow wells since 1947, during which time the population has increased from a handful of farmers to more than 60,000 residents.

There are many cases of contamination of the underground water supply by arsenic, brine, acid, and other industrial wastes. Last year an unusual case was recorded, again in Levittown, N. Y.—that of passage of more than 1 p.p.m. of residual chlorine in sand and gravel formations in the zone of saturation about 400 ft. to a nearby public supply well from a recharge basin receiving the backwash from the filters for a swimming pool chlorination plant.

The outstanding corrective properties of the sand, gravel, silty-clay, and associated materials are indicated by the sanitary quality of water from wells that induce infiltration from polluted and contaminated rivers, such as the Ohio River. Because of dilution by surface runoff, the concentration of chemical substances in the industrial wastes is reduced appreciably in the river. Bacterial action in the moving sediments of the river bottom and very slow percolation in the aquifer tend to dispose of pathogenic organisms, and usually provide water safe for human consumption. No artificial treatment is usually required, although chlorination provides an added factor of safety. Odors and tastes are reduced, if not eliminated entirely. Although the content of the dissolved chemicals is that of the source water, phenols reportedly are removed and the quality is the same or better in many cases than after treatment by artificial processes above ground. A safe and sanitary water supply for many cities and towns is obtained from wells or collectors that induce infiltration of river water.

Subsurface waste disposal cannot be resorted to indiscriminately; if not controlled it will create greater and more

difficult problems than will some other method of disposal. Many integrated and interrelated factors need to be evaluated fully in connection with underground disposal. These include the amount and kind of domestic sewage and industrial wastes and the ratio of one to the other, availability of land surface space and of sand and gravel formations, population total and density, degree of industrialization, cost of structures and appurtenances, etc. They are affected importantly by the intention to use or not to use the fresh or saline water from the underground formations subsequently. They may point to the economy of subsurface disposal up to a certain time and a certain set of conditions, and then to the need of treatment entirely by artificial means above ground for eventual disposal to a river or the sea.

Subsurface disposal can be effective, efficient, and economical under certain conditions and in certain localities, but each problem should be given individual appraisal. A duly considered decision is required as to whether subsurface disposal can and should be made, and if so, whether to formations containing fresh water that are or will be developed for public supply, industrial, or other uses, or to formations containing saline water from which there is no intention at present to pump such water but conceivably there may be in the future. If subsurface disposal is practical and safe, the next question is whether it should be made after treatment, and also when, where, and how much pretreatment of industrial wastes should be required.

The result of such consideration and planning should be the full assurance that the water will be safe at all times and for all purposes intended now or possible in the future, and that the established standards of sewage treatment for a water supply will be met.

At present the total demand for water for the many uses in the national economy is small compared to the total annual natural replenishment. But with the ever-increasing population and standard of living in this country, the per capita use will surely increase and may be doubled in the next 25 years. Thus, the spread between natural supply and demand will decrease, necesssitating, with the passing of the years, more judicious conservation and re-use of the water supply. Serious consideration will be given to the utilization of ground-water reservoirs on a much larger scale than in the past for receiving waste waters, but only those waters that have not been spoiled for further use or that can be made safe and satisfactory by movement through unconsolidated formations. Thus, subsurface disposal in accordance with the best engineering and geologic knowledge, and under full legal control, promises to play a much more important role in the future.

S. Mogelnicki, Research and Development Engineer, Waste Disposal, The Dow Chemical Co., Midland, Mich.:— At present, after about four or five years, we are successfully disposing of about 3,000 g.p.m. of waste brines by subsurface means. The brine wastes result from the processing of the natural brines that lie in the Dundee and Upper Monroe formations at Midland, respectively 4,000 and 5,000 ft. below ground level. Both are of the open sand and sandstone types.

There have been several problems connected with this method of brine disposal. Briefly, the brines leaving the processing plants are impounded in storage ponds, where any flocculent hydrates are allowed to settle. They are then pumped from the other end of the pond through pressure filters to leave the brine as free as possible from suspended matter, and then distributed to outlying wells through pipes going out in four directions from the central point of the plant.

Disposal is to both the Upper Monroe and the Dundee formations. No production brine is currently being

drawn from the Dundee formation. All is being drawn from the Sylvania or the Upper Monroe formation.

Question from the Floor:—What pressure is used on the wells?

Mr. Mogelnicki:—Although the brine has a specific gravity of 1.25, some of the wells will take it right out of the pipe line without pressurizing, at a rate as high as 1,000 g.p.m. Other wells require pressure in order to take even several hundred gallons per minute.

Mr. Lusczynski:—As regards travel of toxic elements in underground aquifers, one experience may prove interesting. A private domestic well downgrade from one of the aircraft factories in Suffolk County, Long Island, showed a high chromium content. The family using the well was induced to go to the hospital to be examined, in view of the fact that the standards call for a low tolerance as far as chromium is concerned.

The family didn't want to stay in the hospital more than one day and insisted on continuing to drink water from that well. At the last report there were indications that the chromium content was about 25 p.p.m., but the users are still alive.

Voice from the Floor:—The U. S. Bureau of Mines has published quite a bit of literature concerning the question of brines in the petroleum production field. There are six or seven reports covering research work done in Kansas on brine disposal, going down to deeper brine formation underlying the oil to a depth of some 4,700 ft.

There are literally hundreds of such wells in operation, probably constituting the biggest use of underground waste disposal.

L. F. Oeming, Chief Engineer, Michigan Stream Control Commission, Lansing, Mich.:—I am a little disappointed in the response that the underground disposal method is receiving here, as I feel that it has very definite possibilities. It is not limited only to disposal of brines from the chemical processing and oil industries, but also has possibilities for some of the wastes that are very difficult to treat. Such wastes include those being produced in the pharmaceutical industry.

The method also should be useful in connection with taking waters from the ground that are highly contaminated and are used for cooling purposes only. I have in mind one industry that during the summer takes from the ground a good deal of cold water that is very high in hydrogen sulfide content. The industry is returning some of that water now and will put more back to get rid of an extensive and severe pollution problem.

In another case, phenol-bearing brines are going back to underground formations at the 1,200- to 1,500-ft. level, as well as phenol waste from the manufacture of synthetics.

L. H. Enslow, Editor, Water and Sewage Works Magazine, New York, N. Y.:—Underground disposal has great appeal; out of sight, out of mind. Everybody likes that, but it isn't like polluting a stream or lake. If a stream or lake is polluted the first good freshet or even discontinuing the pollution will help to restore it. But when underground strata become saturated with something you don't know a thing about, it may take a good many years to clear up.

Mr. Mogelnicki:—At Midland we have observation wells in order to keep track of the static level in the formation into which the waste is being introduced. At no time is waste injected at a rate that will raise the static level to the point where it will get up into the overlying drift.

H. L. Jacobs, Engineering Service Div., E. I. du Pont de Nemours and Co., Wilmington, Del.:—We have inquired of a great many states as to what their attitude would be on underground disposal into brine waters. Many of the states consider those brine waters and deposits as a resource which they do not want to tamper with, and in many

places you can't get permission to put the wastes into underground strata.

David B. Lee, Director and Chief Engineer, Bureau of Sanitary Eng., State Board of Health, Jacksonville, Fla.:—Many of the proponents of disposing of wastes by drainage wells have ruined Florida's water resources. One of our favorite stories is that 10 hr. after a waste went underground they were drinking it.

To get a permit to put any wastes underground in Florida it is necessary to apply to the Bureau of Sanitary Engineering, State Department of Health—and approvals are no longer given. Underground disposal is tampering with one of the greatest resources—water. I agree that out of sight, out of mind, seems to be the general idea of getting rid of waste. Instead, it should be kept up where it can be seen, so that it will be on the public conscience.

C. O. Huntress, Engineer, J. F. Pritchard and Co., Kansas City, Mo.:—As City Manager, I saw a town in Oklahoma forced to spend tremendous sums of money to develop a water supply free from salt. In fact, the chloride content sometimes reached 1,800 p.p.m., which is pretty high, especially in a city water supply. That salt pollution was due to the earlier inefficient practices in drilling and operating oil wells. We were just unlucky enough to be in the drainage area for many of those wells in Kansas and Oklahoma.

On the other hand, experience later in charge of salt-water disposal for the production department of a petroleum company taught me that large quantities of water could be disposed of underground, although the process had to be carefully controlled.

Many factors must be taken into consideration: geology, engineering, expense, and the methods of treatment. With careful consideration of those factors there is no reason why the brines cannot be disposed of underground. Without careful control, however, serious damage can be done to the aquifers.

With present-day recognition of the problems and the careful engineering control needed, there seems no reason why certain wastes cannot be disposed of underground as well as treating them or disposing of them on the surface.

Gordon E. Mau, Sanitary Engineer, State Board of Health, Lawrence, Kans.:—Kansas probably has more brine disposal wells than all the rest of the states combined. All the states surrounding Kansas have lost municipal water wells due to brine pollution. Several Kansas wells have been threatened, but to date not a single Kansas city has lost underground water supply because of oil field activities.

Several surface supplies were threatened. In fact, some of them were probably completely impaired, at least temporarily, for domestic use. One of the streams placed in this condition has been referred to by Mr. Huntress. However, for the last 10 years I do not believe the chlorides have been over 250 p.p.m. at any time where it crossed the Kansas line. Therefore, if brines are disposed of into a mineral-like water formation below an intracurvous geological formation, no danger will be afforded to a water supply, provided the injection well is properly constructed.

Furthermore, in some cases fresh water has been pumped to dissolve one formation, which has been disposed of to a deeper formation, using the cavern to store liquid petroleum gas during the summer weather so it can be pumped out for use during colder weather.

Mr. Lusczynski:—Underground disposal is a very controversial issue. Basically there are two schools of thought—those who would not put any possible contamination underground, and those who would consider the possibilities under controlled conditions.

I do not intend to take sides. My feeling is simply that, although at

present the difference between use and original replenishment from precipitation has a large spread in favor of large supplies, despite shortages in some areas, there is perhaps at this time much less need for consideration of subsurface disposal where there is any intention of using water from the underground system in the future. However, as the population of the country increases, as the per capita use increases, and as the gap between original replenishment and demand narrows, we will need to give further and more serious consideration to subsurface disposal.

Lagooning with Sodium Nitrate

Chairman Hess:—The next topic is lagooning with sodium nitrate. Lagooning in suitable soil would be a simple method for preventing waste liquors from reaching public waters if an unlimited amount of cheap land were available nearby. However, even in this case, some types of wastes would present a public hazard and others would present an odor nuisance.

Furthermore, some types of soil allow seepage into and pollution of surface or subsurface waters. Beyond that, the practical limitations on the size of lagoons usually require periodic discharge of the liquor into public waters and disposal of settled sludge.

The present discussion is primarily concerned with those waste liquors which can be treated with sodium nitrate to avoid odor nuisance and render the effluent acceptable for discharge into public waters.

Harvey G. Rogers, Director, Division of Water Pollution Control, State Board of Health, Minneapolis, Minn.:—Minnesota experience with lagoons has been limited to observations involving the disposal of wastes from vegetable canning plants. Some years ago Minnesota developed quite a little industry in connection with vegetable canning. It did not take long for the Department of Health and others associated with nuisance problems to discover where each of the plants was, because of the problems associated with the disposal of the wastes.

The ordinary treatment methods available at that time were either excessive in cost or unsatisfactory with respect to their efficiency in handling this type of waste. Therefore, the most obvious thing to do was to construct lagoons of sufficient size to store the waste and permit discharge into the streams during periods when stream conditions were much more favorable than they were during the season in which the canning companies operated.

The amount of waste discharged from these plants, amounting to some 35 to 50 m.g., a season, was a considerable problem. The strength of the wastes and the various differences in manufacturing processes caused a discharge of wastes at a very unfavorable time of the year, under conditions likely to cause serious odor conditions.

Sodium nitrate was suggested as a means of making oxygen available so that the odor might be reduced. In a good many cases sodium nitrate was found to be a valuable tool in overcoming these nuisances. However, the problems associated with the construction and operation of lagoons in many cases accrued beyond the facilities made available by the addition of the sodium nitrate.

The ordinary recommended requirements for sodium nitrate, based on the amount of peas in cans or corn in cans, provided a starting point. However, the other features of the design of the lagoon were much more important; that is, the depth of the lagoon and its location with respect to nearby buildings and habitants.

In several cases it was found necessary to use large quantities of sodium nitrate. In other cases even uneconomical amounts of nitrate did not eliminate odors.

Looking into the future, the companies in this particular activity have

turned to another direction for the disposal of their wastes. The sodium nitrate provided a temporary means of making continued operation of the lagoons, and therefore of the factories, possible.

It is not expected that the use of this method for this particular type of waste will continue much longer. It has served its purpose and, when used within its limitations, has been a satisfactory method of accomplishing the results for which it was intended.

O. J. Muegge, Sanitary Engineer, State Board of Health, Madison, Wis.: —The Wisconsin State Board of Health also has had some experience with lagoons on vegetable cannery wastes. In fact, it has had a rather extended experience with lagoons, particularly at cheese factories.

In the early days it was the practice for the cheese maker to dump his waste at the most convenient outlet, thereby often creating miniature lagoons. In the vegetable canning industry, the first lagoon in Wisconsin was installed about 30 years ago. The lime treatment used in that initial lagoon was not too satisfactory. Although isolated, the lagoon produced odors that were objectionable to the community.

Because of the difficulty with the first installation, the number of lagoon installations increased slowly. In the 10-year period ending in 1942, when sodium nitrate was introduced, only 14 lagoons were installed. Some of those used lime, some used caustic soda, and some attempted to use an oil seal to control odors. They were not too successful. The only ones that worked reasonably well were those located over sand or gravel deposits where good drainage was available and anaerobic decomposition was not a factor.

With the development of the sodium nitrate treatment, a considerable number of canneries installed lagoons. At present, there are some 53 cannery waste lagoons in operation in Wisconsin. During the 1951 season, 28 of those used sodium nitrate, 14 used a deodorant known as Polycide, 11 used other agents, some continued with lime, some with caustic soda, and some with an oil seal and another commercial deodorant.

With proper operation it is feasible to dispose of vegetable cannery waste satisfactorily by means of a lagoon. To accomplish this objective, the lagoon should be of sufficient size to provide dilution. At least 25 per cent of the lagoon capacity should be retained as stabilized waste from the preceding operation.

Sodium nitrate should be added when and if necessary, and in amounts as proven necessary to control it. It is our experience that if the B.O.D. in the lagoon can be kept under, say, 300 p.p.m., with an occasional case of 400 p.p.m., there should be no detrimental effects due to odorous conditions. In a cannery, of course, that means keeping out the strong wastes, such as the silage juice from the pea vines or the corn stalks.

Lagoons should be prepared before each season's operation by removing the weeds and any foreign material that may affect the sodium nitrate use or contribute to the load in the lagoon.

In Wisconsin, the lagoons that are operating successfully have a sodium nitrate addition that runs from nothing to 238 lb. per 1,000 24-can cases packed.

In the operation of a lagoon, D.O. decreases, B.O.D. decreases, and plankton increases for about the first two weeks after the waste is introduced each season. It then stabilizes, unless exceptionally strong waste, such as silage juices, are discharged therein.

Immediately after the close of the pack, there is a pronounced drop in B.O.D. In some cases this has been as great as from 800 p.p.m. to about 50 p.p.m. within a 2-week period after the waste discharge ended.

Commercial deodorants have not proven too satisfactory. One that was

tried seemed to have an inhibiting effect on the organisms present and temporarily stopped stabilization. The Polycide previously referred to did not inhibit growth of organisms, and permitted stabilization. The results, however, were not too satisfactory, as there were odors of decomposition and of the deodorant in rather sharp ranges at times throughout the pack.

In one place during 1951 an attempt was made to use brewer's yeast. The method followed was to inoculate the lagoon at the beginning of the pea pack and at the beginning of the corn pack with about 250 gal. of brewer's yeast. At the end of two weeks no yeast was to be found in the lagoon, so that apparently was not a helpful procedure.

As Mr. Rogers has indicated, the current trend is to go to sprayed irrigation of cannery waste instead of installing more lagoons. Lagoons will, however, continue to be used, particularly on wastes from peas, which quite frequently are packed after the growing season has ended.

Another innovation is being tried in lagoon operation in Wisconsin in that one plant, or three plants, actually, have small experimental lagoons for the disposal of spent sulfite liquor. In one place where 30,000 g.p.d. of sulfite liquor are being added to a lagoon, the B.O.D. concentration has been reduced from more than 10,000 p.p.m. in the raw waste to about 1,000 p.p.m. in the water seeping from the lagoon towards the stream. That is an excellent reduction, even though the B.O.D. is still high. The other two installations are barely getting under way, so no data are available.

There is also one instance of a plant handling milk waste by spray aeration preceding 5-day storage in a lagoon. It has proven satisfactory to the extent that the stream conditions below the plant have been materially improved. The actual B.O.D. reduction in that particular instance is not known.

Morris N. Lipschuetz, Chemist, New York State Conservation Department, Rochester, N. Y.:—In connection with the use of sodium nitrate, the nitrate, of course, is reduced to ammonia. That fact should be taken into consideration when the use of sodium nitrate is suggested.

Mr. Ryan:—In New York State there are a few smaller lagoons, like those in Minnesota and Wisconsin, that have given successful treatment. In one at Rushville, N. Y., 95 per cent B.O.D. reduction has been found possible.

It is necessary to hold the waste in lagoons for quite a period of time so that the warm weather will aid. Nitrate currently is not used because of its scarcity.

Preparation of a lagoon is probably as important as the preparation of an Imhoff tank or any other type of treatment unit. We prefer depths of 5 ft. or less, and that the earth be bulldozed from the inside if possible. That eliminates trouble with rats in built-up dikes.

In New York, the preference is for the longitudinal direction to be east and west, so as to take advantage of the wind.

One of the troubles with lagoons is that the users do not leave them in action long enough before removing the effluent. Lagoons can be operated successfully, but they need just as much care as any other type of treatment.

Robert S. Ingols, Georgia Institute of Technology, Atlanta, Ga.:—An experience during the summer of 1952 with a stream receiving a considerable amount of peach canning waste may be of interest. In this case the strong waste was lagooned in contra-distinction to the practice in Wisconsin. This was done because the canning plant was right in the center of town and enough space could not be provided to lagoon the entire waste from the plant. It was necessary, therefore, to reduce the load on the stream by lagooning just the strong waste.

The stream became so septic that it

was giving off considerable hydrogen sulfide. At one of the deep points on the stream the minnows were the only life that could be seen, and they were near the top and breaking surface continuously.

The practice was instituted of adding 100 lb. of sodium nitrate directly to the stream during every hour of plant operation. Something on the order of 3 tons of nitrate were added to a stream flowing not more than 3 or 4 c.f.s. This material went into a pond with about 4- or 5-day detention and at no time were any fish killed.

It is not believed that the reduction of sodium nitrate goes invariably to ammonia, although it is possible that it may under some conditions. Certainly, under many conditions the reduction of nitrate goes to nitrogen and would not, therefore, leave a toxic end problem. If the ammonia is toxic, certainly fish would have been killed in the pond mentioned, and this did not occur.

Mr. Muegge:—The lagoons being operated in Wisconsin, and the same probably is true in Minnesota, are holding-type lagoons. The waste is held for an entire season and is not discharged until it is fully stabilized. Usually that occurs during the spring runoff season, when quite a bit of dilution is available. The B.O.D. at that time may be as low as 20 p.p.m.

Mr. Rogers:—It is impossible to discharge wastes directly to streams during the war months when the canning plants are in operation. The lagoons freeze over in winter. The treatment is incidental. The stabilization is incidental. It is a question of being able to take advantage of high stream flows during the spring runoff.

Anaerobic Digestion

Chairman Hess:—The next topic is anaerobic digestion. One of the big problems in the abatement and prevention of water pollution by industrial wastes is to eliminate oxygen depleting components from waste liquors.

In this connection industry to a considerable extent is adopting the processes of the sewage treatment plant, which in turn are based on nature's own methods.

It seems logical to apply anaerobic digestion or fermentation to treatment of concentrated wastes. There are, however, many questions that must be answered as to type of waste to which it is applicable, design of equipment, and conditions of operation if the method is to be applied successfully.

W. J. Fullen, Chemist, George A. Hormel and Co., Austin, Minn.:—The anaerobic digestion of packinghouse waste has been a research program of the George A. Hormel Packing Company for the past 3½ years. During the first 18 months the work was done on a laboratory scale. For the past 2 years the research has been confined to the present pilot plant, which is capable of handling up to 10,000 g.p.d. Adequate instrumentation and controls have been provided, and a competent machine shop and adequate laboratory facilities have been available.

The pilot plant is operated continuously; that is, 24 hr. per day, 7 days per week. The week end procedure is to either circulate the entire contents or to feed a weak waste. Samples are analyzed daily. The conclusions briefly reported here were arrived at from laboratory and operating records of the pilot plant for the past 2 years. (See THIS JOURNAL, **25**, 5, 576; May, 1953).

The method is essentially a "contact" process, in which raw waste is kept in intimate mixture with an acclimatized activated anaerobic sludge. This is accomplished in an insulated, closed digester maintained at a temperature of 92° to 94° F. The sludge is subsequently separated from the digester effluent, and returned to the digester.

The salient features revealed by this research are as follows:

1. Packinghouse waste is peculiarly adaptable to the anaerobic treatment because the thermal and mineral requirements are intrinsically present. The organic carbon and nitrogen seem to be present in such a ratio as to produce an ideal substrate for the methane-producing organisms.

2. Packinghouse wastes of a wide range of organic concentration can be digested in 24 hr. or less, producing effluents showing a 95 to 96 per cent reduction of B.O.D.

3. B.O.D. loadings of the digester ranging from 0.067 to 0.084 lb. per cubic foot per day have been used in these tests.

4. A practical vacuum method of continuously removing entrained gas prior to sedimentation of the digester effluent is described.

5. The anaerobic method seems to have economic advantages both in construction and operation over the conventional aerobic biological method.

6. Compactness of design is an attribute of the method. A suggested layout for a plant to handle 1 to 1.5 m.g.d. occupies an area of about 0.5 acre.

George J. Schroepfer, Professor of Sanitary Engineering, University of Minnesota, Minneapolis, Minn.:—An interesting phase of the anaerobic process concerns the thermal requirements. Anaerobic digestion has been used now for quite a number of years and it has always been the impression that the wastes had to be quite strong—in the neighborhood of 10,000 p.p.m.—for the process to be as economical as it generally has been considered. It is possible to set up a thermal balance in a process like this, taking the B.t.u. of the influent wastes, plus the B.t.u. value of the gas, minus the radiation losses from the system, and the added heat requirements. In some cases there is an excess of heat, which should equal the heat content of the effluent.

Based on a 95° F. digestion temperature, the annual values of added heat requirements for raw waste temperatures of 60°, 80°, and 90° F. are $5,000, $10,000, and $15,000, respectively. This particular study was based on a volatile solids content of 1,200 cu. ft. in the 1-m.g.d. plant.

Comparison of this volatile solids content with the standard anaerobic processes commonly used and for this size plant, the indicated savings, at a raw waste temperature of 85° F., were about $10,000 a year.

Using this strength of waste, the added fuel requirements are zero when the temperature of the raw wastes is 88° F. If, however, the temperature of the raw wastes is 75° F., the added fuel requirements of $10,000 completely offset any possible savings in the process.

Incidentally, the values given are based on no heat recovery by means of surface-type heat exchangers or heat pumps. There is, of course, a great heat content in the effluent when the digestion temperature is 95° F. It might be possible to recover some of that heat, as suggested in Aukland, New Zealand; a heat pump might be used and might be quite efficient.

On 600-p.p.m. wastes the waste would have to be around 90° F. in order to have a heat balance. At 1,800 p.p.m. heat balance would be attained if the wastes were at 80° F.

Studies of this type have been made on wastes as strong as 6,000 p.p.m. For such a concentration, raw wastes at 60° F. would require about $4,500 per year for fuel requirements. On the other hand, the same wastes at 65° F. would give an available excess of heat valued at $22,000 annually.

The foregoing are all based on 95° F. digestion. If it is possible to digest at 90° F. with the same digester capacity as has been found in these studies, additional savings in heat can be made. At 90° F., to get a heat balance, the waste can be approximately 5° cooler than at 95°.

In general, it is economical to have the wastes as strong as possible by not

admitting clean waters, but in the anaerobic digestion process it is even more important to have warm wastes.

Mr. Jacobs:—In this process is the digester inoculated with sewage, or are the bacteria already in the waste?

Mr. Fullen:—The digester was started with primary and secondary sludge obtained from the City of Boston.

Mr. Enslow:—What is the composition of the gas, as compared with ordinary sludge gas?

Mr. Fullen:—It is just about the same, probably about 60 to 80 per cent methane and between 20 and 35 per cent carbon dioxide. The net fuel value is about 600 B.t.u. per cubic foot.

High-Rate Filters

Chairman Hess:—High-rate filters, the subject of the next section of the Forum, might be regarded as an improvement on nature's own aerobic processes. Man's machines are used to produce conditions that do not exist in nature.

Just what is the latest knowledge about these conditions and how are they applied to industrial wastes?

D. S. Merritt, Project Engineer, Campbell Soup Co., Camden, N. J.:—High-rate filters usually are associated with secondary treatment or relatively complete treatment. The investigation reported on in the following, however, is on the use of a high-rate trickling filter as a "scalping" filter, or in a way similar to a "scalping" screen in the removal of suspended solids.

Chemical treatment and sedimentation has been accepted by several states as a means of treating cannery wastes in those cases where only partial reduction of the B.O.D. is required. Reduction of B.O.D. by chemical treatment and sedimentation presents problems in sludge disposal which may make the process very costly.

If the cannery is in the open country, disposal of the bulky sludge can be accomplished quite cheaply by lagoons. But if the cannery is in an area so built up that no suitable vacant land is available for sludge lagoons, filtration and incineration of the sludge are necessary. The cost of equipment for filtration and incineration is great enough to make this process of waste treatment prohibitive for a seasonal manufacturer.

Furthermore, the effectiveness of chemical precipitation and sedimentation in reducing the B.O.D. of cannery waste, varies considerably as the constituents of the waste vary; that is, the more soluble B.O.D. contained in the waste, the less effective sedimentation becomes in reducing the B.O.D.

In the case under discussion screens removed suspended solids to the required point, making it necessary only to reduce the B.O.D. of the effluent to a point where it could be handled by the municipal treatment plant.

Therefore, an investigation was undertaken to determine the effectiveness of a high-rate trickling filter when used for only partial removal of B.O.D. from soluble cannery waste; that is, if the filter could be used for a partial B.O.D. removal in the same way that a scalping screen is used in the removal of suspended solids? Such an investigation was carried on by the speaker under the direction of Messrs. F. W. Mohlman and K. V. Hill.

It was known that the bulk of the suspended solids could be removed from the waste by either rotary or vibrating screens using wire cloth with an opening of 1 mm. (18 meshes per inch). Consequently, the trickling filter pilot plant was constructed without the usual chamber for settling the waste before applying it to the filter. By eliminating primary settling of the waste one point of sludge accumulation was avoided.

The filter used in this investigation was a wooden tank 20 ft. in diameter containing a 6-ft. bed of crushed trap rock. The rock selected for the filter bed was coarser than usual, being

screened to be retained on a 2½-in. screen and to pass a 4-in. screen. Many pieces of the rock, although passing a 4-in. screen in cross-section, were 8 or 10 in. long. The result was a very porous bed with large voids. No difficulty was experienced from clogging of the filter, provided the pH was properly controlled, but whenever the pH dropped below 6.0, a noticeable growth of mold developed within a few hours. This is not surprising when one considers that tomato washer water, containing sugars, acid from split tomatoes, and mold fragments removed by the washers, was a major constituent of the waste being treated.

Whenever mold growth appeared on the filter it entrained quantities of fine suspended solids and built up into such a thick incrustation that anaerobic conditions developed, with accompanying disagreeable odors. Increasing the pH of the influent to 8.0 corrected the condition promptly, however, by killing the mold. It is concluded, therefore, that close pH control is necessary for the satisfactory operation of a high-rate trickling filter as a scalping filter for any cannery waste or soluble organic waste where mold growth may develop.

A recirculation ratio of 5 to 1 was found to be the optimum condition of recirculation. Recirculation at this ratio increased the B.O.D. removal per acre-foot per day by 120 per cent over a recirculation of 3 to 1. Increasing the recirculation ratio to 7 to 1 increased the B.O.D. removal by only 8 per cent more.

Prior to this investigation it was expected that the maximum loading of the filter would be around 7,000 or 8,000 lb. B.O.D. per acre-foot per day. Several tests were made at loadings of 10,500 to 11,500 lb. B.O.D. per acre-foot per day. No difficulty was encountered from clogging or from offensive odors at these high loadings. The reduction accomplished varied from 40 per cent at 7,500 lb. B.O.D. loading to 32 per cent at a loading of 11,500 lb.

The maximum rate of B.O.D. removal was 3,400 lb. per acre-foot per day, and occurred at a loading of 9,000 lb.

From this investigation it is concluded that a high-rate trickling filter provides an attractive means for partial treatment of cannery waste that is high in soluble B.O.D. and low in suspended solids, because sedimentation and sludge disposal are not necessary.

C. H. Nichols, Merck and Co., Rahway, N. J.:—The high-rate filter was brought to reality by Jenks in 1936. Development and successful use of trickling filters that can take four to five times the B.O.D. that can be handled on conventional trickling filters, has been a definite advantage from a capital cost viewpoint and also from the viewpoint that it can take a much greater liquid loading per unit of surface area.

Unit B.O.D. loadings of 1.5 to 2.0, or even up to 4 lb. per cubic yard are now common. Liquid application rates ranging from 15 to 30 m.g.a.d. are used on these filters. The higher liquid rates occur usually with the lower B.O.D. application rates. Continuous sloughing in high-rate filters permits a more active growth, giving a higher degree of treatment.

High loadings of more than 4 lb. of B.O.D. per cubic yard can be applied in cases where the biofilter is used as the first unit in series with a successive filter. Recirculation ratios are relatively high with the biofilter units, ranging from three to five times the main flow.

Biofilter efficiency, at the lower loadings and measured in terms of B.O.D. removed in passing through the unit, ranges from 70 to 85 per cent. Where an additional biofilter unit is used to handle the settled effluent from the first biofilter, the over-all efficiency may be increased about 10 per cent.

The high-rate trickling filter or biofilter has a stone depth of about 3 to 4 ft., as contrasted with the 6- to 9-ft. depths in the standard-rate filters.

With the high biochemical and liquid loadings on this type of filter, critical factors of design are important. Such items as adequate liquid velocity in the tile drains, and proper ventilation, are important. A minimum liquid velocity of 2 ft. per second should be used in the drain. A 70 to 80 per cent freeboard to give good air circulation to feed the bacteria and increase the oxygen content of the liquid in the filter is important.

Another important factor of design is in the specifications of the stone used in biofilters. Calculations show that the percentage of free space between the stones is not much different in sizes ranging from 1½ to 4 in. However, if the stone is long and flat this free space is decreased, adversely affecting aeration and preventing the filter from carrying on its normal sloughing cycle. As nearly cubical shapes as possible should be used. Certain types of limestone have a tendency to crush into flat pieces; others are more uniformly shaped. Good grading and washing of the stone before placing in the biofilter are important items.

Biofilters can accept excessive intermittent biochemical loads of three to four times their normal design rating without seriously affecting their performance. However, poisoning by metals (lead, copper, zinc, chromium, etc.) can cause drops in efficiency requiring lengthy periods for recuperation.

In that portion of the nitrogen cycle covering conversion from nitrites to nitrates, nitrification in a high-rate filter is lower than in standard filters, largely due to the lower bed depth. However, the higher oxygen content of the liquid waste from a biofilter may assist in by-passing the nitrate cycle, with direct conversion from nitrite to ammonia and free nitrogen in the presence of anaerobic bacteria. At the same time, the lower B.O.D. from the high-rate filter (due to higher efficiency) may make the ultimate completion of the nitrification cycle unnecessary.

Biofilters have very little odor and a minimum fly population, due to the high liquid application rate. It has been shown that a marked decrease in toxicity to fish and fish food organisms takes place during the biofilter treatment operation.

The increased use and consistently good performance testify to the soundness of the biofilters, particularly in industrial waste applications.

J. A. Liontas, Sharpe & Dohme, Philadelphia, Pa.:—Was any difficulty experienced with solid batches in handling the wastes on the filters?

Mr. Nichols:—The pilot work was carried on during bad batches and good batches, without apparent effect on the operation of the biofilters. They are able to accept bad conditions for a reasonably short period of time and stay within a good operating range. Of course, once the filters are knocked out they take a long time to recover.

Question from the Floor:—Do you use pH control?

Mr. Nichols:—All the wastes are collected in an equalizing basin, which serves the dual function of pH equalization and removal of suspended solids. Wastes from the basin are just about at pH 7.0.

As has been pointed out, the cost of sludge disposal is rather high. It was estimated to cost about $150,000 to put in equipment to handle the sludge. Exploration of other methods led to adoption of land disposal. On plowed land the sludge digested in a short time and there was good drainability.

Application rates between 0.2 and 0.4 g.p.d. per sq. ft. were tried, through all types of weather. Of course, in rainy seasons we couldn't plow. In cold weather we have had no trouble, but in warm weather frequent plowing is necessary.

Question from the Floor:—What was the concentration of the sludge put on the land?

Mr. Nichols:—About 1,300 to 5,000 g.p.d., containing about 3 per cent solids, are applied.

Question from the Floor:—Is it intended to use any kind of aeration prior to filtration?

Mr. Nichols:—Experiments on aeration were very successful, giving B.O.D. reductions of 50 to 70 per cent. The aeration is not of the conventional type. In one plant taken over by the company the concrete basins were already there, making aeration attractive from an economy viewpoint. However, we would like to try a filter system because of its stability of operation, its economy of installation, and its low operating costs. No real survey has been made to determine which is the cheapest, the decisions having been largely governed by the existing situations.

SULFITE PULP WASTE LIQUOR RECOVERY

A new process for recovery of waste liquors from sulfite pulp mills was described by Arthur Pollack and Robert S. Aries, chemical engineers of New York, N. Y., at a recent joint meeting of the American Institute of Chemical Engineers and the Chemical Institute of Canada, held at Toronto, Canada. Named the "Sulfox" process (derived from "sulfur oxidation"), the process adapts to the sulfite pulp mills a process that has been successfully used in sulfate (kraft) mills for a long time—burning the liquor and re-using the chemicals involved. The process also can be applied to neutral sulfite pulping, a method of pulping hardwoods that is rapidly coming into wide use.

About 60 mills in Canada and the United States now dump their spent sulfite liquor. For these, the Sulfox process appears to offer a practical solution to waste disposal problems.

In the new process the spent liquor is evaporated and burned to an ash in the same kind of equipment now used in kraft mills. This is practical because common soda is used in place of the lime, dolomite, magnesia, or ammonia now used in sulfite mills. Its use does not impair the quality of the pulp and, in fact, there is some evidence that such a pulp has advantages.

As in kraft mills, the ash from burning sulfite liquor is a mixture of sodium sulfide and carbonate. The sulfide is oxidized to sulfite by a procedure which the inventors have been able to reduce to a surprisingly simple operation. The product is a powder of mixed sodium sulfite and carbonate, which is fortified with sulfur dioxide in the equipment already available at all sulfite pulp mills. Any soda lost in the cycle also is added, the resulting batch being the cooking liquor ready for the pulp mill.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

SELLING THE PUBLIC ON SEWAGE TREATMENT

Although public health protection by sewage treatment should be the concern of each and every member of the vast group known as "the public," it is astounding how many people take it for granted or ignore it entirely. Yet it is only by actively interesting these very people in the necessities for and problems of sewage treatment that the money usually can be made available for construction, improvement, and operation of this type of facility.

One of the best means of awakening the public to a consciousness of its responsibilities in sewage treatment is the age-old process of education—as to what sewage treatment is, how it performs, and what the problems are. Seldom does the result suddenly shine forth; generally the awakening takes place gradually, over a long period, and only as a result of much active salesmanship.

Like charity, this education should begin at "home," which in this case means the sewage treatment plant. The problem, of course, is to get the people you want to reach to visit the plant. Once that is accomplished the selling job should be comparatively easy.

What one small plant operator does about visitation promotion is contained in a recent communication from W. L. Edwards, senior operator of the sewage treatment plant serving the State Hospital at Gowanda, N. Y. Said Mr. Edwards:

"Personally, I am a great believer in trying to educate the public in the advantages of sanitation, particularly that phase concerning sewage treatment. Most people think of sewage treatment as consisting of just a couple of holes in the ground with a smelly atmosphere, and therefore shy away from visiting the plants.

"As a means of getting people to visit this plant I have sent out letters to the schools, the youth organizations, and the several civic organizations. This has been done through the cooperation of the director and business officer of the hospital, who is in accord with the basic idea.

"The results are apparent in the many people who visit the plant, and the comparatively large proportion who are amazed that the water leaves the plant in such good condition and that the gas from sludge digestion can be utilized for heat and power.

"Each month a group of the hospital employees visits the plant and inspects the different operations. Every three months different hospitals in Buffalo send their student nurses to this hospital for a course in mental hygiene and care of the patients. These affiliated students visit the plant as part of their course. The Boy Scout and Girl Scout troops of the surrounding territory also visit the plant periodically, as do other civic and service groups.

"Once people have visited the plant they tell others about it and arouse their interest. I try to point out to each visitor the value of sewage treatment as it affects the health and future of himself and his children. I take a great deal of pride in the plant and its proper functioning and appearance, and deem it a pleasure to conduct people through it, explain it to them, and answer their questions. Visitors are always welcome at the plant, which is clean and efficient and a satisfactory place to bring men, women, and children for an instructive inspection, complete in all details."

H. P. O.

DIGESTER SCUM CONTROL AT SYRACUSE, N. Y.*

By Uhl T. Mann

Superintendent, Ley Creek Sewage Treatment Plant, Syracuse, N. Y.

Although the digestion of sludge is a rather intricate and complex process, its control is relatively simple if the factors controlling the process are maintained in the proper balance. With proper control and with the absence of inhibiting materials it is almost impossible to stop the process.

This discussion deals with one of the most troublesome operating problems encountered with digestion in separate units, namely the formation of top scum. A complete description of the process, as well as discussion of the design factors and equipment usually incorporated in a digestion unit, is beyond the scope of this paper.

The top scum to which this paper has reference is the type that reaches a depth of 3 to 5 ft. and acquires a consistency which makes it impossible to be moved by pumps. This condition is not universal, but appears to be a serious problem in many plants employing separate digestion units.

The presence of scum at the top level of digesters presents the following problems:

1. Loss of capacity.
2. Increased cost of operation.
3. Danger of damage to the structure in the event that scum prevents normal overflow of the digester.

Scum Problem is Man-Made

Today there are several mechanical devices that are helpful in controlling the scum problem; but none of these devices eliminates the condition. In fact, after many years of operation experience with digesters at the Ley Creek sewage treatment plant in Syracuse, N. Y., the author is thoroughly convinced that the scum problem is man-made. The digesters at this plant comprise four 30,000-cu. ft. tanks with fixed covers and a 15,000-cu. ft. gas holder with floating cover.

The Ley Creek plant experienced difficulty for a 9-year period, during which ground screenings and scum were pumped to the digesters. In two years the scum would reach a depth of about 4 ft., necessitating dewatering of the tank and removal of the accumulated scum to restore capacity needed for normal operation.

In each instance it was necessary to break up the scum with high-pressure water from a hose before it could be pumped. In many plants the top sludge is often a mass of ground screenings, grease, and raw sludge; at the Ley Creek plant it was a mass of screenings, grease, and digested sludge. Apparently the discharge velocity carried the scum-forming material down into the tanks so that it carried particles of digested sludge with it as it rose to the surface. This condition should have aided digestion of the scum, but apparently the scum-forming material was not in suitable size and shape to permit proper seeding of scum material.

With regard to this condition it would be well to point out that the success of any decomposition process depends on intimate contact of the bacteria and other microorganisms with the sewage solids providing their source of food. For example, aerobic decomposition in aeration tanks is more rapid than anaerobic decomposition in a digestion tank because the rather violent agitation in an aeration tank insures far greater contact of the organisms with the organic material providing their food supply. It is very

* Presented at 1953 Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; January 22–23, 1953.

difficult to provide intimate contact of bacteria with materials in the form of heavy scum.

The materials that are normally caught on a bar screen and are ground or cut up by some means, never approach the minute size of normal organic solids macerated by long periods of travel in sewers.

Grease removed with scum collects at the top of digesters, making it difficult to have intimate contact with the methane-producing organisms. Studies on pilot digesters some years ago showed that grease digested quite readily, but a mixture of grease and ground screenings required twice as long for digestion. In addition, materials like rags, hair, straw, and small pieces of wood never digest in a normal cycle and must eventually be removed from the digesters. Another item that has added to scum troubles has been the increased use of paper towels by industrial plants. This type of paper requires a considerably longer digestion period than do toilet and facial tissues.

Screenings Increase Digestion Time

Rudolfs (1) reported that screenings were successfully digested at Milwaukee, Wis., on a 40-day schedule. The required digestion capacity was

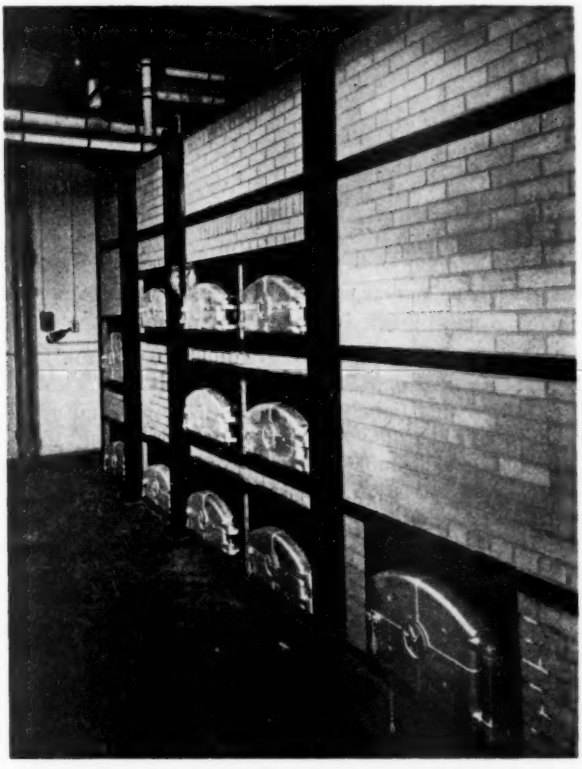

FIGURE 1.—Incinerator at Ley Creek plant burns screenings and primary settling tank skimmings. Charging openings are on floor above.

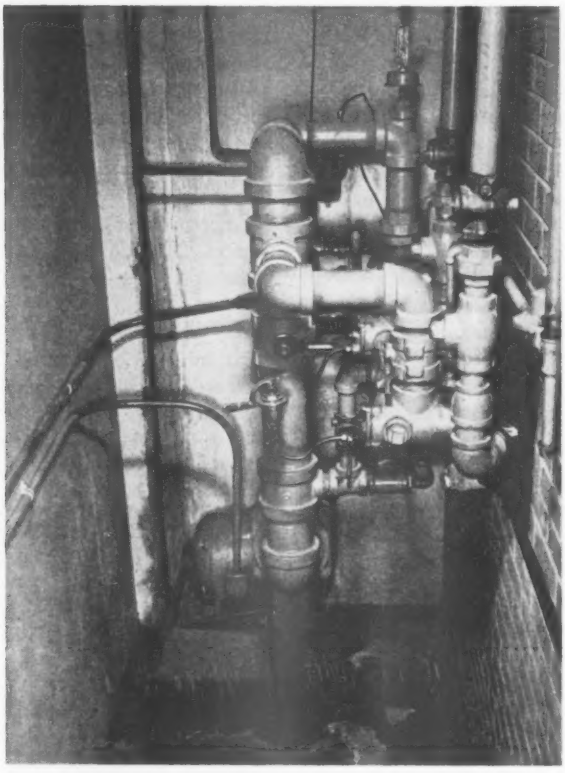

FIGURE 2.—Dual-fuel burners use sludge gas, oil, or both to fire incinerator.

estimated at 1 gal. per capita. On this basis the Ley Creek plant would require 14,000 cu. ft. of additional capacity. It is of interest to note that during the period of scum troubles at Ley Creek the loss of digestion capacity due to scum amounted to about 16,000 cu. ft. Even with added capacity, there still would remain the problem of removing from time to time the materials that never digest. The same studies showed that although properly seeded activated sludge digested at 70° F. in 30 days, replacement of 10 and 20 per cent of the sludge volume by screenings increased the digestion period to 35 and 40 days, respectively.

The studies at the Ley Creek plant showed that the digestion of sludge with screenings and grease required a longer period than for sludge alone. Also, the gas produced with screenings and grease was greater, but the volume of gas produced per pound of volatile matter was lower than with sludge alone. The most pertinent fact in the Ley Creek studies was the loss of capacity due to the building up of a heavy layer of scum, which reduced the active capacity of the unit.

It is not intended to imply that screenings and grease should not be digested, but to point out that because of their nature it is extremely difficult to create the proper environmental

temperature and to get proper mixing and seeding. If screenings and greases could be reduced to the size and shape of the majority of organic sewage solids, and kept in suspension in a digestion unit, there is no doubt that a normal digestion cycle might be expected.

Remedial Measures

During the past four years no screenings or skimmings from the primary tanks have been pumped to the digesters. At present there appears to be about 1 ft. of scum, which is quite soft and pliable and which can be pumped.

At the beginning of this program the only method of disposal of screenings and skimmings was by burial. This method is cumbersome and expensive, requires considerable area, and is most difficult in freezing weather.

During a recent construction program an incinerator (Figure 1) was installed for burning screenings and skimmings. The specifications called for capacity to incinerate to complete combustion sewage screenings of approximately 90 per cent moisture content at the rate of 1,000 lb. per hour.

The incinerator was equipped with dual-fuel burners to burn gas, oil, or any combination of both fuels. The present operating program is to preheat with gas, use oil with gas to facilitate burning, and then to use gas alone to complete burning. The unit is operated three days per week, with 4 to 5 hr. of burning time required per day.

The incinerator has proven to be an economical and simple means of disposing of screenings and primary tank skimmings.

During 1952 the average monthly quantities of screenings and skimmings were 849 cu. ft. and 250 cu. ft., respectively. On the basis of sewage flow, these quantities amount to 5.2 cu. ft. of screenings and 1.5 cu. ft. of skimmings per million gallons. No attempt has been made to calculate the cost of destruction of this material. It might be of interest to point out that during 1952, 13,188 cu. ft. of screenings and skimmings were burned at a cost of $965.77 for fuel oil, plus additional use of surplus gas for the balance of the fuel required.

If the current digester capacity of 240,000 cu. ft. were operated with the same scum problems encountered at the plant 10 years ago, there would be a loss of 36,000 cu. ft. of digester capacity, with a value of nearly $50,000.

The digester scum control method outlined in this discussion is not proposed as a cure-all for everyone's scum problems. Those who have none may consider themselves fortunate; for those who have, it is the purpose of this discussion to point out that at the Ley Creek plant an investment of $14,000 for an incinerator has provided for simpler and more efficient operation, plus a saving of digester capacity valued at many thousands of dollars.

Reference

1. Rudolfs, W. *Jour. Boston Soc. Civil Eng.* (1929).

INTERESTING EXTRACTS FROM OPERATION REPORTS

"The ladder of job success is admittedly full of splinters; but they hurt most when you're sliding down—not going up."—*Anon.*

Attention operators. It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage and Industrial Wastes Associations, Room 325, Illinois Bldg., Champaign, Ill.

12th Annual Report of the Kenosha, Wis., Sewage Treatment Plant for the Year 1952

By Frank I. Vilen, *Superintendent*

General

The Kenosha sewage treatment plant is designed for primary treatment of 10 m.g.d. of sanitary and industrial wastes. Separate sludge digestion units and chlorination facilities also are provided. Approximately 90 per cent of the sewer system is combined.

The daily average sewage flow in 1952 was 16.23 m.g.d., or 60 per cent above the design flow. During the year the maximum was 26.03 and the minimum 7.80 m.g.d. At a per capita consumption of 100 g.p.d., sanitary flow amounted to 5.55 m.g.d. The estimated industrial flow was 4.60 m.g.d. The remainder, 6.08 m.g.d., or 37 per cent of the total, was storm flow and ground-water infiltration, which was no doubt partially due to the extremely high water level in the Great Lakes during the period.

Kenosha sewage is weaker than the average for cities with comparable sewer systems, presumably because of the character of the major local industrial wastes (metal fabricating and processing). The 1952 average for suspended solids was 121 p.p.m. and for B.O.D. was 115 p.p.m., as compared with generally accepted values of 200 and 180 p.p.m., respectively. As the flow has increased during the past few years the suspended solids concentration has decreased. A similar trend is apparent in B.O.D., except in the past two years, which showed an increase. Dilution by lake and ground water may account for the weak character of the Kenosha sewage.

The year 1952 was marked by extremes in temperatures and precipitation. Total precipitation was about 2 in. more than the average. July was the wettest on record, with 5.66 in.; October was the driest on record, with only 0.03 in. Average temperatures were about normal throughout the year, with the annual mean at 46.3° F. The hottest day (104° F.) was in July and the coldest (− 9° F.) in January. Temperatures above 90° F. were recorded on 23 days; below zero temperatures occurred on 4 days.

Treatment efficiencies continue to be good as compared to acceptable standards for primary treatment. It is interesting to note that total sludge solids removed increased only 7 per cent over 1951, whereas the flow increased 11.6 per cent.

Industrial Wastes

Because of the high copper content of the sewage, regular determinations of toxic copper concentrations are made

on raw sludge and digester contents. Measured as dry solids, copper in the digesters averaged 0.37 per cent in 1952 and 0.44 per cent in 1951. A close check is maintained for evidence of cyanides, chromium, and other substances that may be toxic to treatment processes. Copper compounds remain, however, the major inhibitory substances received at the plant.

TABLE I.—Summary of 1952 Operation Data for the Kenosha, Wis., Sewage Treatment Plant

Item	Average
Rainfall (in.)	31.05
Sewage flow (m.g.d.)	16.23
Pop. served (est.)	55,500
Grit removed (cu. ft./m.g.)	0.35
Susp. solids (p.p.m.):	
Influent	121
Effluent	56
Reduction (%)	54
Sett. solids (ml./l.):	
Influent	1.34
Effluent	0.08
Reduction (%)	94
pH:	
Influent	7.4
Effluent	7.4
B.O.D., 5-day (p.p.m.):	
Influent	115
Effluent	51
Reduction (%)	55
Chlorine demand (p.p.m.):	
Influent	7.4
Effluent	4.5
Raw sludge data:	
To primary (gal./day)	6,440
To secondary (gal./day)	6,450
Solids (%)	8.73
Dry solids (lb./day)	9,430
Vol. solids (%)	58.3
pH	6.8
Grease (%)	23.1
Dig. sludge data:	
Solids (%)	17.3
Dry solids, total (tons)	698.3
Vol. solids (%)	43.9
Grease (%)	13.5
Sludge gas data:	
Gas produced, total (m. cu. ft.)	11.805
Per m.g. sewage (cu. ft.)	1,990
Per lb. dry sol. (cu. ft.)	3.42
Per lb. dry vol. sol. (cu. ft.)	5.94
Per cap. daily (cu. ft.)	0.56
Supernatant:	
Dry solids (%)	0.47
Vol. matter (%)	54.6
Operating cost ($):	
Total	66,143.88
Per m.g.	11.13

Gas Production

Total sludge gas produced in 1952 was slightly more than in the previous year. On a unit basis, however, less gas was produced. In 1952, 5.94 cu. ft. of gas was produced per pound of dry volatile solids added. This compares with 6.31 cu. ft. in 1951. The demand for pumping and heating was greater, and 95 per cent of the total gas production was utilized. The supply fell far short of the total requirements and it was necessary to purchase 3,400,000 cu. ft. of natural gas to make up for the deficiency.

Enzyme Experiment

A "bottle digester" experiment was carried on over a period of 20 weeks to determine the effect of an enzyme product on digestion. Two experimental units were used, with both being fed equal amounts of the same raw sludge daily in proportion to plant-scale feedings. The enzyme preparation was fed to one of the digesters as recommended by the manufacturer. Gas production was measured daily by water displacement.

At the end of the experiment, the contents of both digesters were analyzed (a) separately as supernatant and sludge, and (b) after thorough mixing, as a composite of the contents. The raw sludge averaged 6.96 per cent total solids, of which 60.1 per cent were volatile. Results of the experiment were as follows:

Sample	Vol. (ml.)	Total Solids (%)	Susp. Solids (%)	Vol. Solids (%)	pH
Control:					
Supernatant	4,820	0.985	0.945	56.5	7.3
Sludge	4,640	20.38	—	42.3	7.3
Composite	9,460	11.29	—	41.4	7.3
Enzymes added:					
Supernatant	4,640	0.47	0.31	64.0	7.4
Sludge	4,720	19.35	—	40.8	7.35
Composite	9,360	7.64	—	39.6	7.4

This experiment was made to check the very attractive claims made for the product as an aid to digestion. Its

high cost, however, precluded any use on a plant scale without some preliminary investigation. Particular interest was centered in improving gas production to reduce operating costs. Apparently use of the enzymes does aid digestion to some small degree as measured by the reduction in volatile matter; gas production was 9.98 cu. ft. per pound of volatile matter in the control digester and 10.47 cu. ft. with the additions of the enzyme produce. It is understood, of course, that no definite conclusions can be made from one experiment of this kind. On the basis of this one experiment, however, the value of the 5 per cent increase in gas production does not warrant the cost of this material for use on a plant scale.

Operating data for 1952 are summarized in Table I.

Annual Report of Operation of the Delaware (Ohio) Sewage Treatment Plant for the Year 1951

By L. T. Hagerty, *Superintendent*

The year 1950 having been none too successful from a sewage treatment standpoint, due to the high concentration of industrial wastes received at the sewage plant, completion of the Ranco * waste treatment plant was anticipated during 1951.

High river stages resulted in shutdown of the municipal plant on all but 10 days in January and 16 days in February, providing opportunity for cleaning both Imhoff tanks. Internal inspection of both tanks showed them to be in excellent condition considering their age.

After being in operation only a few weeks, the Ranco waste treatment plant had to be shut down, due to failure of the paint lining in a tank on the acid side of their plant. This, of course, added to the load at the sewage plant and upset its functioning on the days it was able to operate.

Correction of the trouble at the Ranco plant during March enabled return to more or less normal operation. In May, however, a further breakdown necessitated addition of lime to the raw sewage to neutralize the acid waste received from Ranco during a 5-day period. Another 2-day breakdown required raw sewage liming again in June.

In July, lime, chlorine, and sodium nitrate were added to the filter influent in an effort to relieve ponding and to improve bacterial action, which had been almost at a standstill. Sloughing after about 5 days indicated some favorable results.

No digestive action was apparent in the Imhoff tanks until mid-October, with only a slight increase in gas action noticeable even at the end of the year.

TABLE II.—Summary of 1951 Operating Data for the Delaware, Ohio, Sewage Treatment Plant

Item	Average
Sewage flow (m.g.d.)	0.886
Susp. solids (p.p.m.):	
Raw	152
Settled	102
Final	48
Reduction (%)	68
B.O.D., 5-day (p.p.m.):	
Raw	159
Settled	151
Final	48
Reduction	70
pH:	
Raw	7.2
Final	7.3
Total solids (p.p.m.):	
Raw	756
Final	640
Diss. oxygen (p.p.m.):	
Final effl.	4.4
Stream above	9.4
Stream below	6.6
Operating cost ($):	
Total	16,260.88
Per m.g.	57.96

* See This Journal, **23**, 11, 1429 (Nov., 1951).

During this period, however, bacterial action in the filter seemed to be increasing. The low removals of suspended solids and B.O.D. by the plant are ascribed to the metals received in the Ranco wastes, which during the year showed the following analysis:

Item	Av., 8 mo.	Monthly Av.		Daily	
		Max.	Min.	Max.	Min.
Flow (m.g./mo.)	1.847	2.149	1.452	—	—
Chromium (p.p.m.)	2.1	4.1	0.5	8.25	0.1
Copper (p.p.m.)	2.89	4.1	0.03	11.2	0.0
Cyanide (p.p.m.)	0.42	1.1	0.2	10.2	0.0
Nickel (p.p.m.)	0.56	2.0	Tr.	8.0	Tr.
pH	9.2	9.8	8.7	10.7	6.3

Removal of the Ranco metals by treatment in that company's plant probably will improve operation of the municipal plant by allowing near-normal digestion in the Imhoff tanks and better filter efficiencies. An attempt to reduce upsets caused by by-passing of Ranco wastes directly to the municipal plant without treatment is being made by installation of a lime feeder discarded from the water treatment plant and re-installation of a chlorinator that has not been in use for several years.

The 1951 operating data are summarized in Table II.

GLASS ELBOW ELIMINATES SLUDGE PUMPING GUESSWORK

By Henry J. Rieping

Superintendent, Sewage Treatment Plant, Monticello, N. Y.

For more than a year after the Monticello, N. Y., sewage treatment plant was placed in operation, trouble was experienced with pumping of primary sludge. Because of being unable to tell the condition of the sludge being pumped, it was almost impossible to know how much of the material being pumped to the digesters was sludge and how much was sewage.

The situation also had other disconcerting aspects. For example, efforts to keep the volume of sewage introduced into the digesters at a minimum from time to time resulted in insufficient sludge pumping. This caused the sludge to become so heavy that it plugged the primary settling tank sumps, necessitating draining of the tanks and a messy job of sludge removal.

In this plant sludge from the primary and secondary settling tanks flows by gravity to a pair of interchangeable sludge pumps in the operating building. From here it is pumped to the digesters, which are on a hill 400 ft. away and at a head of 36 ft. All piping is of 6-in. diameter cast iron.

Glass Pipe Suggested

To remedy the situation, a local chemical engineer suggested installation of a glass pipe section, which would enable observation of the sludge during pumping. The arrangement apparently is not new, but is used in acid and other chemical plants.

A letter to the Corning Glass Works, Corning, N. Y., brought a referral to a regional distributor of specialty glassware, who in turn sent a representative to the plant to determine if a glass pipe section was feasible. It finally was decided that the best place for the sight glass was at an elbow in the control building near the pumps.

Pyrex glass pipe is made by the Corning firm in sizes from 1- to 6-in. inside diameter, in lengths up to 10 ft. Fittings also are available in 90° and 45° elbows, tees, laterals, crosses, and

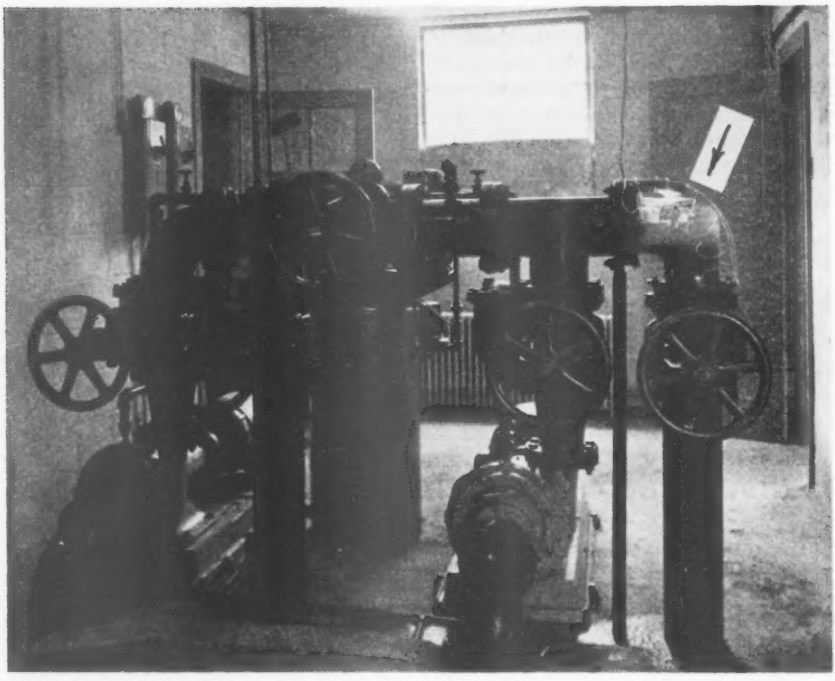

FIGURE 1.—Glass elbow in sludge piping permits operator to see condition of material being pumped to digester.

U-bends for the same pipe sizes. In addition, the company furnishes the special flanges, bolts, and gaskets needed for the installation, which is simple and can easily be done by almost anyone.

In the Monticello case, the elbow needed was not of standard dimensions. However, Corning Glass Works made one up especially for the purpose (Figure 1), at a total cost of $72. A wire guard was installed to protect the glass fitting from damage by external shocks.

Since installation of the sight glass, no guesswork is involved in sludge pumping. Not only is it possible to see the exact condition of the sludge being moved, but the observation also can be made inside the control building at a point near the pump controls.

THE DAILY LOG

New Britain, Conn.

By John R. Szymanski, *Superintendent*

March 4—Every once in a while the suppliers of ferric chloride find themselves rushed, and the supply of ferric chloride becomes scarce. After anxiously waiting for a shipment we discovered that it had been routed to cover 500 miles more than necessary, thus the delay. The spirit of coopera-

tion seems to prevail amongst most plant superintendents, and I find a phone call will arrange a loan of materials—thanks to Hartford and Waterbury. It's mutual, of course, and the material is replaced as soon as possible. The State Department of Health called regarding an inspection of all sewer overflows—a sure sign of spring!

March 5—Personnel morale has been at rock bottom because of the new compensation-classification plan (see THIS JOURNAL, **25**, 2, 226; Feb., 1953). Obvious inequalities have shown up, which we hope to iron out eventually. It's a task facing a sullen group each day and watching orders carried out half-heartedly.

Signed final easement papers granting the Hartford Electric Light Company the right to run a power line through the old sand filters along a 150-ft. right of way. Real estate business—however, it fattened up our Repair and Renewal Fund quite a bit.

The new 2,000-c.f.m. blower is in place, and quotations were requested today for the electrical work involved.

March 10—After juggling schedules since January 1 trying to cover all shifts with the regular staff used on a 48-hr. weekly schedule, it was decided that two more men in the labor class would relieve the strain of the new 40-hr. schedule. Spent all morning interviewing prospective laborers. It's odd to note the variety of qualifications possessed by a few of these men and to note the attitude some applicants have as compared to applicants of 10 years ago.

March 13—A complete check of all overflows was made this morning in conjunction with the State Health Department authorities. A special check also was made on the wastes discharged from the local general hospital, the special sample being checked closely for radioactive isotopes.

March 14—The usual problem of grit prevails again. Some day, soon, we hope we can ease this to a point of tolerance.

Completed all contracts for chemical supplies for the next fiscal year. Surprisingly there was only a slight increase over the preceding year, caused mostly by increased freight rates.

March 17—St. Patrick's Day—all is green and O.K. This is a wonderful country; for example, the mixed group of 18 employees at the plant is comprised of Poles, Italians, Irish, Russians, Germans, Lithuanians, and Ukrainians, and we still respect each others "special days."

After due deliberation it was decided that it would be more economical to turn in the 1948 Chevrolet dump truck and purchase a new one rather than overhaul the old one. Requests were sent out to five dealers in town for quotations on a new truck.

March 18—Accepted an invitation to participate in an industrial wastes forum at the Spring Meeting of the New England Sewage and Industrial Wastes Association. It's amazing how much one learns in preparing to talk to others or teach others.

The changeover from a 48-hr. work week to a 40-hr. work week seems to keep popping up all around; Walter Anderson, Superintendent of the plant at Cranston, R. I., sent in a request for our schedule make-up in order to compare.

March 19—The steam boiler insurance company inspector gave our heating system its annual inspection. A 35-lb. pressure relief valve had to be changed to a 25-lb. one on one of the spare hot-water tanks. Otherwise, everything was O.K.

March 21—Usual operations. By "usual," we don't mean normal; at present "usual" means handling a 50 per cent overload in flow, etc.

After correcting an existing discrepancy in the meter readings of the Kensington Fire District, we were able to bill it for services for the past year. Kensington and Berlin are towns ad-

jacent to New Britain, and arrangements are such that New Britain has agreed to treat the sewage from these towns on a cost basis. A power factor, determined at the pumping station, is applied to the monthly power readings to determine the quantity of sewage pumped to New Britain for treatment.

March 24—Spent a half day with the auditors, who were spot-checking the city payrolls—it's an annual occurrence.

March 28—The new 2,000-c.f.m. blower is finally ready for operation. This unit was installed to replace two original 500-c.f.m. blowers that just simply worked themselves to death on a work schedule of 24 hr. per day for 16 years.

March 29—For the sake of review, a lubrication engineer from one of the major oil companies was called in to discuss our complicated lubrication program.

April 4—It was decided to purchase another new blower. This one is to be similar to the original—namely, a 500-c.f.m. unit—thus giving us one 2,000-c.f.m. and two 500-c.f.m. units, and doubling the air available for treatment.

April 9—The plant group does its part in keeping abreast of community activities. For example, today a representative was delegated to the Cancer Fund drive committee.

April 10—An interesting communication was received from England this morning. An operator, Mr. Zboinski, after reading a summary of the New Britain sewage treatment plant's operation in the JOURNAL decided that he could seek counsel from us on one of his pet projects; namely, the question of sludge disposal. In his letter he also enclosed some excellent drawings covering his ideas. After looking them over and consulting with other men in this field, the prints were returned to Mr. Zboinski with constructive comments.

April 29—A general review and study of the existing employee classification and compensation plan is being made in an effort to equalize the various classes pertaining to the plant employees. This is being done by the Commission and the Civil Service personnel director. It is believed that the revision will be fair and help maintain a high standard of employment at the plant.

A pleasant duty was performed today in attending the annual Connecticut State Sewage Operators' Forum, conducted by the State Department of Health at Hartford.

April 30—The committee trying to set up a Short School for sewage plant operators at the University of Connecticut met today. It seems, from all reports, that an air of procrastination exists in most communities on this matter.

May 8—One of our top-notch operators resigned today. After 15 years of sewage work, he decided to enter the private vacation resort business in Maine.

Professor C. Meyer, from Worcester Polytechnic Institute, brought a group of his sanitary engineering students to the plant for their annual visit.

May 15—The annual report for the year 1951–2 was completed today and is in the mail. This brought the sudden realization that another year has gone by.

May 22—Skeleton crews at work—the New England Sewage and Industrial Wastes Association meeting was being held in Waterbury. With the meeting that close, all hands that possibly could do so were in attendance.

June 5—Each extra available man-hour is being used as a "paint-hour" at the plant. In previous years the painting program was spread out during the entire year. However, with the 40-hr. work week, time off for holidays, and a two-week vacation period, it is difficult to maintain the old painting schedule.

June 10—The chlorinators were serviced extensively by the manufacturer. The units are fast becoming obsolete and it is believed that some thought should be given to their full replacement.

June 13—The union steward suggested that plant employee grievances be handled by an employee grievance committee of three, who will meet with the plant superintendent monthly to discuss said probable grievances. The first such meeting was held today. It had some merit, but not as much as anticipated.

June 17—A state-wide air raid drill was held today. As a result of our 100 per cent participation in this drill we uncovered many details which should be corrected for the future—just in case.

CAN DIGESTER RECIRCULATION BE OVERDONE?

By Walter A. Sperry and Williard P. Pfeiffer

Superintendent and Assistant Superintendent, respectively, Aurora Sanitary District, Aurora, Ill.

This article is a brief recounting of experiences with digester recirculation at the Aurora, Ill., treatment plant that practically amounts to a sewage plant detective story.

It was believed that the low gas returns of the years 1950, 1951, and the forepart of 1952, averaging 31,000 cu. ft. per day, might be increased if a sludge recirculating pump was applied to the primary digester. This belief was based upon the following possible advantages:

1. Mixing of the "seed" sludge with the raw incoming primary sludge.
2. Reduction of scum layers, although scum was never a serious problem.
3. A more uniform total solids content of the sludge transferred to the second-stage digesters.
4. A more uniform temperature throughout the digester.

Further arguments that favored applying recirculation included the fact that recirculation has been considered advantageous since before 1929 and most modern digesters now apply it in connection with external heat exchangers.

The Aurora plant has three fixed-cover digesters, each 50 ft. square and 16 ft. deep. Each has a 41,500-cu. ft. capacity. Two are used as secondary digesters, the third being used as a primary digester and receiving all the primary sludge. All are heated by coils and a hot-water boiler system, so that the applied recirculation was independent of the heating system.

The 350-g.p.m. recirculating pump was positioned outside the digester 5 ft. above the digester floor and with the suction extending 5 ft. inside the center line of one wall. The discharge was carried just under the roof and within 5 ft. of the opposite wall. The digester contents were, therefore, recirculated completely every 15 hr., or 1.6 times per day.

The new pump was placed in operation July 2, 1952, and run continuously. Gas production in July averaged 41,650 cu. ft. per day, with a maximum daily production of 56,200 cu. ft. on July 23. Gas production continued favorable through August 13, averaging 44,000 cu. ft. with four days of the 13 better than 50,000 cu. ft.

The First Episode

On August 14 gas production in the first-stage recirculated digester began to fall off from an average of 36,500 cu. ft. to 1,300 cu. ft. on August 19. It remained at about this level for the remainder of August.

At the time, the gas loss was assumed to be due to a toxic slug. Possibly this conclusion was reached because of the rapid drop in the gas volume. This resulted in a frantic laboratory search for the cause—in the best of sleuthing tradition. Analytical methods for determining cyanides, copper, and chromium were searched out and the tests applied. Many friends lent valuable aid, including the Chicago Sanitary District and the state laboratories, but to no avail.

Aurora industries were examined as to their procedures and the Chamber of Commerce and the Manufacturer's Association were questioned as to any new and unknown industries. However, Aurora had no industries with a toxic waste other than the usual small plating operations. These had been operating for years and all were applying the usual and proper precautions. In short, no copper, chromium, or cyanide was found in sufficient amounts to explain the difficulty.

Cyanides in the raw sewage ran from 0 to 1.14 p.p.m. and averaged 0.2 p.p.m. Copper ran from 0 to 60 p.p.m. in the primary sludge on the wet basis, from 0 to 0.8 p.p.m. in the raw sewage, and from 14 to 40 p.p.m. on the wet basis in digester No. 1. During this period chromium was absent in the raw sewage, although the primary digester sludge showed 6.4 p.p.m. and the No. 3 digester sludge showed 1.6 p.p.m. No nickel was found.

In the meantime, numerous tests for toxic waste had been run on sewage liquors collected from various points on the interceptor system that might show sources of poison in various areas of the city where were located known and possible sources of trouble. Nothing came of these efforts, however.

Meanwhile, the pH in the primary digester dropped to a low of 5.9. The pH of the primary sludge ranged from 5.9 to 8.5 and averaged 6.6, which was generally normal for primary sludge.

The free ammonia in the primary digester ranged from 120 to 200 p.p.m. About August 30 the volatile acids in the ailing digester were 6,400 p.p.m. and the gas contained 59.6 per cent CO_2 and would not burn. By September 12 the CO_2 content of the gas had returned to its normal 30 to 34 per cent. Volatile acids in the primary sludge varied from 550 to 2,240 p.p.m. At the time the relationship of the high volatile acids to the problem was not recognized.

Remedial measures included liming the digester system, using a total of 6,900 lb. of slaked lime, applied mostly to the primary digester. Also, 400 lb. of lump ammonium carbonate was applied, 200 lb. to the primary and the rest to the secondary digesters. This restored the pH of the system to 6.5.

The primary digester was emptied and cleaned out completely—once completely and a second time partially. One of the secondary digesters was also partially emptied, on the theory of getting rid of toxic material, since by this time we were convinced that no fresh toxics were coming into the plant.

Meanwhile, the primary sludge was distributed to the secondary digesters at the rate of 20 per cent in August and 44 per cent in September in an effort to maintain these two digesters as near normal as possible. The gas yield in September averaged only 8,900 cu. ft. per day, the primary digester contributing 3,540 cu. ft., the No. 2 digester 680 cu. ft., and the No. 3 digester 4,700 cu. ft.

In October the digester system completely recovered and 82 per cent of the primary sludge was returned to the primary digester. On October 1

the primary digester produced 6,300 cu. ft.; by October 9 it was producing 23,200 cu. ft.; and by October 11 the yield was 33,000 cu. ft., with a total of 51,200 cu. ft. for that day from the system. October 9 was 43 days after the trouble started in August. The month of October averaged 50,000 cu. ft. of gas per day, with 17 days exceeding 50,000 cu. ft., and the maximum days—October 23 and 29—producing 79,000 cu. ft. each.

Thus terminated the worst low gas period in 22 years and we were still undecided as to the cause. We were convinced, however, that it was not due to toxic waste.

The Second Episode

Following the recovery of the system in October, gas production during November and December continued normal, averaging 49,000 cu. ft. per day. On January 12, 1953, however—95 days after the October recovery—the primary digester gas yield again declined, this time from 25,600 cu. ft. per day on January 12 to 4,500 cu. ft. on Jan. 19. This looked like a repetition of the August trouble. Ever since the October recovery weekly tests for toxics had been run as a routine procedure. None were found of troublesome proportions. The cause had to be sought elsewhere.

It will be recalled that the recirculation pump applied to the primary digester on July 2, 1952, had been run continuously on a 24-hr. schedule. This schedule had been under suspicion, but not seriously until now. Tests for volatile acids in the primary digester showed amounts between 5,000 and 6,000 p.p.m. This was strong evidence of overloading and lack of balance. The digester, therefore, was immediately dumped on January 20 and reseeded from the No. 3 digester, filled with raw sewage, and placed back in service. In the meantime, the recirculating pump schedule was reconsidered. Instead of shutting the pump down completely, it was decided to operate it on a 2-hr. schedule immediately after the addition of primary sludge. This change was on the assumption that continuous circulation, particularly during sludge additions, would tend to pass seed sludge to the secondary digesters. Very possibly more seed sludge was passed to the secondary digesters than the unsatisfactory sampling methods indicated. Also, although mixing of the fresh sludge with seed was beneficial, a rest period was advisable. Accordingly, on January 31 the pump schedules were changed to three periods during the day when the pump was operated for 2 hr. immediately after primary sludge additions, interspersed with three rest periods of 2 to 4 hr.

This plan resulted in almost complete recovery and return to normal. The gas yields by February 4 were back to 42,500 cu. ft. per day. The February gas averaged 49,120 cu. ft. per day, with a high day of 63,600 cu. ft. and 15 days of gas yields above 49,000 cu. ft.

Some Observations

These two experiences strongly suggested that the cause of the August, 1952, trouble was misjudged and was

TABLE I.—Monthly Average Primary Digester Loading

Month	Total Solids (lb.)		Vol. Matter (lb.)	
	Per Day	Per Cu. Ft. Dig. Cap. per Day	Per Day	Per Cu. Ft. Dig. Cap. per Day
1952:				
July	9,140	0.220	5,500	0.135
Aug.	9,370	0.226	6,000	0.145
Sept.	6,230	0.150	4,200	0.100
Oct.	9,870	0.238	6,900	0.166
Nov.	10,200	0.246	6,900	0.166
Dec.	9,100	0.218	6,100	0.147
1953:				
Jan.	10,230	0.247	6,800	0.163
Feb.	9,310	0.224	5,900	0.142
Average	9,180	0.220	6,040	0.145

really due to digester overloading and that too much recirculating, possibly at the wrong time, caused undue loss of seed sludge to the secondary digesters. They further suggest that the digester was too small for the loading and that the trouble might not have occurred had the digester capacity been larger.

These experiences further re-emphasize the importance of volatile acids as a control test. In a normally operating digester, volatile acids should level off at about 800 p.p.m. and should not exceed 2,000 p.p.m. During the January, 1953, experience and until the recirculating pump schedule was changed, volatile acids ranged from 3,870 to 6,500 p.p.m. in the primary digester. The pH ranged from 6.0 to 6.5. After the change of pump schedule on January 31, volatile acids were run as a daily routine and ranged from 940 to 2,040 p.p.m., with the pH ranging from 6.5 to 7.0. Digestion has since been normal.

The immediate result of the study imposed by the August-January trouble was to show the need for a larger primary digester. In fact, its design and construction has already been officially arranged for.

The supporting data include a connected population increase of from 42,000 persons in 1931 to 60,000 in 1953. Also, Tables I and II show the loadings received by the system from July 1, 1952, through February 28, 1953.

There are several yardsticks by which to judge the loadings on a digester other than cubic feet per capita. One such yardstick is stated to be 3 lb. of total solids per cubic foot of digester capacity per month. This is at the rate of 0.10 lb. per cubic foot per day. It will be noted that the Aurora primary digester, for the 8-month period (Table II), carried a loading of 0.356 lb. per cubic foot per day for 35 per cent of the time, inasmuch as on 86 of the 243 days the load applied to the primary digester averaged 14,820 lb. per day.

TABLE II.—Average Primary Digester Loading on Days When Primary Sludge Solids Exceeded 10,000 Lb.

Month	No. of Days[1]	Total Solids (lb.)		Vol. Matter (lb.)	
		Per Day	Per Cu. Ft. Dig. Cap. per Day	Per Day	Per Cu. Ft. Dig. Cap. per Day
1952:					
July	9	17,200	0.415	9,620	0.230
Aug.	10	18,000	0.425	9,940	0.240
Sept.	13	12,000	0.290	7,700	0.185
Oct.	15	12,400	0.300	8,600	0.204
Nov.	14	13,300	0.320	8,780	0.210
Dec.	10	12,980	0.312	8,510	0.205
1953:					
Jan.	9	15,700	0.378	9,060	0.218
Feb.	6	17,000	0.410	9,500	0.230
Average	11	14,820	0.356	8,950	0.215

[1] Days in month when total solids received by the digester amounted to 10,000 lb. or more.

The authors consider this a typical "Operator's Corner" story, in that it reports an experience that may be of deeper significance than is apparent on the surface. The "case" has been described in detail in the hope that it may contain helpful suggestions for others and, more particularly, because so little information concerning similar problems could be found in the literature. No claim is made that the happenings have been correctly interpreted or that the conclusions reached are sound. It is hoped, however, that others may be encouraged to discuss the matter in the light of their own experiences and thereby add to the total knowledge of the subject.

TIPS AND QUIPS

Natural (ly)

Cleaning of the primary digester at Camp Callen, Calif., was recently carried out by the pumping station crews operating from the San Diego sewage treatment plant. According to the *Quarterly Newsletter* of the California Sewage and Industrial Wastes Association, 2 cu. yd. of sand and 18 pairs of dice were removed.

Is further proof needed that digestion is only a gamble?

Scaffold Safety Hints *

1. Erection and removal of scaffolds should be done only by experienced workmen.

2. All lumber used for scaffolding and accompanying platforms should be of spruce, fir, or long-leaf yellow pine. The material should be sound, straight-grained, and free from shakes, large knots, or other defects.

3. Diagonal bracing should be provided to prevent upright posts from swaying or moving in any direction.

4. Free-standing independent pole scaffolds should have a minimum base dimension of not less than 25 per cent of the scaffold height.

5. Guardrails and toe boards should be installed along the edges of all scaffold platforms 10 ft. or more above ground, excepting platforms covering the entire floor space in rooms or buildings, or on platforms where life belts or life lines are furnished and used.

6. All planking used for platform purposes should be tested before being placed in use by setting one end of the plank on a 12-in. rise and jumping on it at the center point. Safe center loading for planks is given in Table I.

7. The clear span of platform planks between supports should not exceed 8 ft. when planks 2 in. thick and 8 in. wide are used and this arrangement should be for only light-duty work. For heavy-duty work, the support

* Adapted from "Your Guide to Safety in the Plumbing, Heating and Ventilating Trades," published by the Accident Prevention Department, Association of Casualty and Surety Companies, New York, N. Y.

TABLE I.—Safe Center Loading (in Pounds) for Planks[1,2,3,4,5,6]

Span (ft.)	2 × 8 Dressed to 1½ × 7¼	2 × 10 Dressed to 1½ × 9¼	2 × 12 Dressed to 1½ × 11¼	3 × 8 Dressed to 2½ × 7¼	3 × 10 Dressed to 2½ × 9¼	3 × 12 Dressed to 2½ × 11¼
6	230	290	355	610	775	935
8	170	210	260	450	570	690
10	130	165	200	355	450	540
12	105	130	160	285	365	440
14	80	105	130	235	305	365
16	70	90	105	200	255	310

[1] As recommended by the Forest Products Laboratory, Forest Service, U. S. Dept. of Agriculture.

[2] Douglas fir, Sitka spruce, white spruce, red pine, and Port Orford white cedar, based on extreme fiber stress of 1,300 lb. per sq. in.

[3] Safe center loading for other types of wood may be calculated by multiplying the safe load shown by the constant for type of wood as listed in Table II.

[4] Values are for planks surfaced on four sides, seasoned, free from shakes, decay, and other defects such as large knots in edge or center of wide face of the plank.

[5] If the planks have been subjected to wetness for prolonged periods the values given are reduced.

[6] The table allows the average 30 lb. per cu. ft. for the weight of the planks. The values shown are the actual pounds which may be placed at the center of the plank.

TABLE II.—Loading Constants for Various Woods[1]

Species	Fiber Stress (lb./sq. in.)	Constant
Balsam fir, ponderosa pine, sugar pine, and western white fir	1,050	0.80
Tamarack	1,400	1.07
White ash, red oak, white oak, and bald cypress	1,500	1.15
Douglas fir (coast region) and southern yellow pine	1,750	1.34
Dense Douglas fir and dense southern yellow pine	2,050	1.57

[1] For use with values in Table I.

points should be placed at 6 ft. intervals when 2-in. by 8-in. planks are in use. The platform shall not be less than 20 in. wide.

8. Any platform or scaffold that was erected for use by others should be thoroughly examined to determine its fitness before being worked on.

9. Runways or ladders should be erected to platforms that are 5 ft. or more in height.

10. Don't jump from scaffolds or platforms.

11. Don't stand on railings of barricades.

12. Don't remove protection guards or barricades without replacing them as soon as possible.

Waste Sludge Gas Used to Heat Large Municipal Garage

Faced with the double problem of (a) maintaining comfort heating in a large municipal and storage garage where winters are severe (−20° F.), and (b) reducing maintenance costs caused by corrosion, the City of Austin, Minn., utilized waste sludge gas from the adjacent sewage treatment plant in a large warm-air space heater having a stainless-steel combustion chamber.

Heating of the structure had previously been accomplished by small suspended unit heaters. These, however, had required constant maintenance because of the combustion chamber corrosion resulting from the sulfide content of the fuel used. Besides the large heat losses resulting from the type of construction (one-story brick and steel of 7,600-sq. ft. area), additional large heat loss is occasioned by frequent opening of the large doors to permit passage of trucks and heavy equipment. The many windows also increase the heat loss.

The new unit was installed in an inverted position in the roof trusses. This not only saved floor space, but also simplified the partial ductwork serving the office, lunch room, and locker room. The inverted overhead position also minimizes heat losses through the roof, as the warm air rising to the roof is reheated and discharged downward into the garage area.

Esquire's "Sludge and Sanctity"

What is probably the strangest story ever told about sewage is an article entitled "Sludge and Sanctity," by Aldous Huxley, in the June, 1953, issue of *Esquire*. The essay is a confused hodgepodge of history, religion, politics, philosophy, and extremely personal hygiene, engendered by visits to Hyperion Beach before and after construction of the new Los Angeles sewage treatment plant.

The author goes to considerable trouble to make his subject as unpleasant as possible, and to bury his theme in a rambling jumble of Esquirian language. One eventually gets the idea, however, that he is trying to say that sewage works such as that at Hyperion are realistic symbols of a mature civilization.

All in all, the whole piece is more dribble than sludge, and more drivel than sanctity.

Reviews and Abstracts*

Systematic Analysis of Organic Industrial Wastes. By H. Braus, F. M. Middleton, and C. C. Ruchhoft. *Anal. Chem.*, **24**, 1872 (1952).

The industrial wastes from petroleum, synthetic rubber, naval stores, coke, and synthetic chemical plants can be analyzed so as to identify the various organic constituents of the waste. Some organic compounds are extracted with solvents, others with steam under various conditions of pH and salt concentration. The products are identified by boiling point, infrared analysis, and derivatives.

R. S. Ingols

Determination of Pyridine and Pyridine-Base Compounds in River Water and Industrial Wastes. By R. C. Kroner, M. B. Ettinger, and W. A. Moore. *Anal. Chem.*, **24**, 1877 (1952).

Because of the taste produced by chlorinating pyridine in polluted waters, it was necessary to develop a sensitive analytical procedure. A modification of the well-known technique for determining cyanides provides a method which can detect 0.005 p.p.m. pyridine or related compounds. The color is developed by using benzidine and cyanogen bromide in a neutral solution; the final step of reaction takes place in butyl alcohol, and the color intensity is measured in the butyl alcohol. Many factors affecting the color development are reported.

R. S. Ingols

Study of Chromium Toxicity by Several Oxygen Demand Tests. By R. S. Ingols and E. S. Kirkpatrick. *Anal. Chem.*, **24**, 1881 (1952).

The data show that the toxic level of chromium is controlled by the valence of the chromium, the type of organism, the amount of organic matter present, and the presence or absence of oxygen. The chromate is much more toxic under anaerobic conditions than the chromic ion, whereas, in general, the chromic ion is more toxic under aerobic conditions than the chromate ion. The chromate ion is reduced at low concentrations under anaerobic conditions. R. S. Ingols

Determination of Microquantities of Iodine in Water Solution by Amperometric Titrations. By H. P. Kramer, W. A. Moore, and D. W. Ballinger. *Anal. Chem.*, **24**, 1892 (1952).

Iodine can be determined with a high degree of precision and accuracy by the amperometric instrument. It must be remembered, however, that iodine itself is unstable because of the formation of iodide and iodate ions, so that much care must be used. R. S. Ingols

Determination of Copper Ion by a Modified Sodium Diethyldithiocarbamate Procedure. By C. A. Noll and L. D. Betz. *Anal. Chem.*, **24**, 1894 (1952).

The interference of iron, zinc, and lead is eliminated from the "Standard Methods" procedure. The concentration of diethyldithiocarbamate is reduced to 1 per cent of that previously recommended, while diluting the ammonia reagent. Good accuracy and precision is possible with the copper and the new, weaker reagents. R. S. Ingols

Biological Analyses of Water and Conditions for Its Use. By Karol Starmach. *Gaz, Woda i Tech. Sanit.* (Poland), **26**, 9, 250 (1952).

Biological analyses should be required for the proper interpretation and evaluation of the sanitary state of any surface waters, and should be made in conjunction with the requisite chemical and biological analyses. Due to a lack of knowledge on

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

the part of water technologists, because of difficulties in the identification of the various organisms comprising the flora and fauna of the stream, and because of difficulties in the interpretation of the findings, biological analyses have not received sufficient attention. In order to develop a program in the biological analytical field, the author presents the following recommendations:

1. Biological analysis of water is indispensible. It serves to verify, complete, and broaden chemical and bacteriological findings in drinking water and sewage.
2. Biological analysis of water must take into consideration all organisms found in the water, in particular those found in quantity. It cannot be based on either macroscopic or microscopic examinations alone, but should include both.
3. Biological analysis must be accurate; it cannot ignore either living or dead organisms. For a true evaluation of conditions both must be considered.
4. Fundamental conditions for the proper execution of biological analyses are special schooling of personnel and standardization of methods of examination.
5. For the schooling of personnel, special faculties and departments should be organized at the polytechnical institutions to consider the problems relating to water technology, and at all higher agricultural schools to consider the problems of fish protection and the agricultural utilization of wastes.
6. In addition to schools for training personnel, experimental stations should be established to study the organisms found in water, particularly plankton and the lower animal forms. These stations are to provide the foundation on which the biological analytical structure will be built.

CONRAD P. STRAUB

Viability of Geohelminth Eggs in Water Courses and Bottom Deposits. BY A. M. USACZEWA. *Gigiena i Sanitaria* (Russia), 12 (1951). Abs. in *Gaz, Woda i Tech. Sanit.* (Poland), **26**, 10, 303 (1952).

Eight sampling points were located on a branch of a stream 26.5 km. in length for the purpose of studying the removal and viability of helminth eggs. In a distance of 20 km., settling (about 90 hr. elapsed time) removed all helminth eggs. (Abstractors note: It is presumed that this stream was inoculated with these organisms and this distance was below the point of discharge or inoculation, although there is no mention of this in the text.) It was found that 80 per cent of the bottom samples showed the presence of helminth eggs. To determine the incubation time of the eggs and their viability in the bottom sediments, fresh cultures of ascarid eggs were prepared and incubated under conditions similar to those occurring in the stream. These studies indicated that the development of the eggs varies in different regions of the stream, and under similar temperature conditions varies (presumably) with the oxygen content of the stream. For example, with oxygen concentrations of 7 to 9 p.p.m., the ascarid eggs developed to the larval stage in two months; with oxygen concentrations of 5 to 5.6 p.p.m., the eggs did not develop to the larval stage; and in the absence of oxygen there was no development of the eggs. Observations on the viability of ascarid eggs placed in tanks in February showed that after 2 months 65.1 per cent survived in water and 56 per cent in the bottom deposits; after 9.5 months, 34.5 and 41.8 per cent survived, respectively; and after 15 months, 11.8 and 17.1 per cent, respectively. It was concluded that bottom deposits in open resevoirs or basins could serve as a source of helminth eggs and that waters so contaminated could serve as a focus of human infection.

CONRAD P. STRAUB

Water Quality Criteria. Publ. No. 3, State Water Pollution Control Board, Sacramento, Calif. 512 pp. (1952).

The printed edition of a mimeographed report abstracted in THIS JOURNAL, **24**, 11, 1437 (Nov., 1952). A limited number of copies are available from the publishing agency, without charge, to governmental agencies directly concerned with water pollution control. Postpaid cost to others is $3.00 per copy (cash with order) from the Documents Section, State Printing Division, 11th and "O" Sts., Sacramento 14, Calif.

Book Reviews

Gewässerschutz und Abwasser-Reinigungsanlagen (Stream Protection and Sewage Treatment). VARIOUS AUTHORS. Verlag Baublatt AG, Ruschlikon-Zurich, Switzerland. No price indicated (1952).

This book is very similar in objective and content to the Federation's Tenth Anniversary Book, "Modern Sewage Disposal," published in 1938. It is an excellent German-language symposium on stream pollution control in Switzerland, on modern practice there in the treatment of sewage and industrial wastes.

The chapter headings and authors are as follows:

1. Need for Stream Protection, and Sewage Treatment Aims in Switzerland; Task and Objective of the Swiss Association for Stream Protection. By Dr. Otto Jaag.
2. The Cleansing of our Streams, a Fundamental of Public Health. By Paul Zigerli.
3. Federal Laws Relating to the Protection of Streams against Pollution. By Alfred Mathey-Doret.
4. Research in Sewage Treatment and Stream Protection. By Dr. Ulrich A. Corti.
5. Historical Development of the Sewage Works Field in Switzerland; Task and Objective of the Swiss Association of Sewage Professionals. By Andre Kropf.
6. Review of Common Treatment Processes for Domestic Sewage. By Arnold Hörler.
7. The Handling of Industrial Wastes. By H. Kuisel.
8. The Need for Regional Sewage Projects and their Fundamentals. By Pierre Wildi.
9. The Development of Metropolitan Sewer Systems and the Location of the Treatment Plant. By Fritz Schneiter.
10. Sewage Services in Small Communities. By Friedrich Baldinger.
11. Sewer Pipe Materials. By Jakob Müller.
12. Fundamentals and Experience in Sewer Construction. By Fritz Bachmann and Arnold Schmid.
13. Operation and Maintenance of Sewers. By Jakob Isler.
14. Household Drainage Recommendations of the Swiss Association of Sewage Professionals. By Friedrich Baldinger.
15. The Importance of Garbage Recovery to Stream Protection. By Georg L. Böttner.
16. The Present Status and Proposed Development of Sewage Treatment in the Various Kantons.
17. Examples of Operating and Proposed Treatment Plants for Domestic Sewage.
18. Examples of Industrial Waste Treatment Plants.

A joint project of the *Schweizer Baublatt* and Verband Schweizerischer Abwasserfachleute, the book is intended (a) to demonstrate to municipal officials that sewage treatment is practical and that current methods are well-founded on experience, (b) to set forth the pollution abatement needs in Switzerland and to show how they may be satisfied, and (c) to stimulate interest in the problem and thus increase public support of waterborne waste disposal projects.

Although slanted basically to Swiss practice, the book is equally representative of technical practice in continental Europe. A feature of particular value and interest is the large number of detailed plant descriptions, profusely illustrated by flow diagrams and photographs.

W. H. WISELY

Sewerage and Sewage Treatment. Seventh Edition. By HAROLD E. BABBITT. John Wiley & Sons, Inc., New York, N. Y. 674 pp. Price, $8.00 (1953).

The seventh edition of this widely used text not only retains the excellent features that have given the earlier editions their outstanding reputation, but enhances its use to student and practitioner alike through modernization and increased

scope of coverage. Among the more notable revisions in the new edition are:

1. Conformation of the nomenclature with the authoritative glossary prepared by a joint committee of the several technical sanitary associations.
2. New design specifications and recommendations of various regulatory agencies, particularly at the state level.
3. Recognition of the advances made in process control and equipment design, as well as in wastes treatment and their applications.

As with the previous editions, the seventh edition de-emphasizes the older methods in favor of newer practices when improvement is indicated, but still retains the fundamental values of the earlier versions, including simplicity, directness, balance, and thoroughness. Also like the previous editions it subordinates the chemical and biological aspects of sewage treatment theory in accomplishing its primary objective of serving as an engineering text. H. P. ORLAND

Water Supply and Sewerage. Third Edition. By ERNEST W. STEEL. McGraw-Hill, New York, N. Y. 582 pp. Price, $8.00 (1953).

This revised text, designed to cover two related fields so as to eliminate duplication, offers the fundamentals of both subjects. Presentation of the theory and practical application of both design and operation of water and sewage works is well-balanced, with stress placed on essential principles and practice rather than on less important details.

The revision of the new edition incorporates the many new advances and practices developed in the fields covered. Rainfall and runoff material has been rewritten, and fuller treatment is given storm-water inlets and sewer maintenance. Self-purification of streams has been consolidated with sewage treatment, the theory and its application being treated at greater length. Sewage filtration, activated sludge, sludge digestion, and sludge lagooning are covered more completely than in the former editions, particularly in view of late developments in these areas.

As a general text for the allied fields covered, the new edition should admirably serve the purpose for which it was intended. H. P. ORLAND

Basic Mechanics of Fluids. By HUNTER ROUSE AND J. W. HOWE. John Wiley & Sons, Inc., New York, N. Y. 245 pp. Price, $4.50 (1953).

This undergraduate textbook deals specifically with the mechanics of fluids, not for a particular class of engineer, but as a grounding in fundamentals for all. Running through the book is a constant theme of application of fundamentals, which are presented in a unified, coherent development rather than as isolated principles. The development in regard to all problems of flow is carried up to the point of juncture with thermodynamics.

The 400 problems included are of very practical flavor, representing applications of the principles discussed to the fluid flow problems of many diverse engineering fields. In general, the book is well-designed to accomplish its purpose as a general engineering text.

H. P. ORLAND

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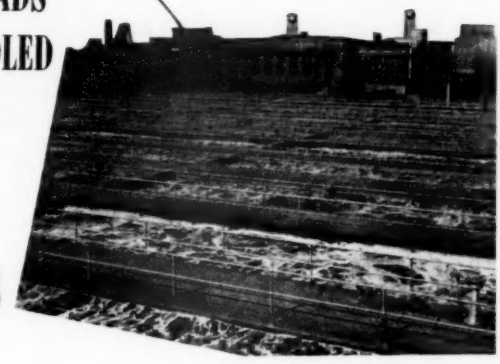

Activated sludge aeration tanks, Peoria, Ill. Three channels in foreground, out of a total of twelve aeration channels, are used for sludge nitrification.

The P.F.T. Kraus Process, also known as the "Digester Liquor Nitrification Process," can be readily applied to existing plants or incorporated in the design of new plants. No additional aeration basins or aeration facilities are required nor any greater amount of air. Only a slight revision in piping and return activated sludge pumping facilities are required.

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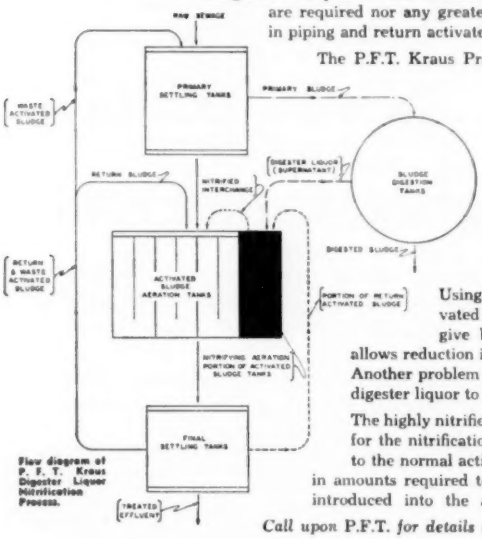

Flow diagram of P. F. T. Kraus Digester Liquor Nitrification Process.

Using this system, sludge produced in the activated sludge process settles more readily to give better overall results in purification or allows reduction in capacity of secondary settling facilities. Another problem is effectively overcome by making use of digester liquor to advantage.

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Proceedings of Member Associations

OKLAHOMA WATER, SEWAGE AND INDUSTRIAL WASTES CONFERENCE

The 1952 Annual Meeting of the Oklahoma Water, Sewage and Industrial Wastes Conference was held December 1–5, 1952, at Oklahoma A & M College, Stillwater, Okla., in conjunction with the 26th Water, Sewage and Industrial Wastes Short Course.

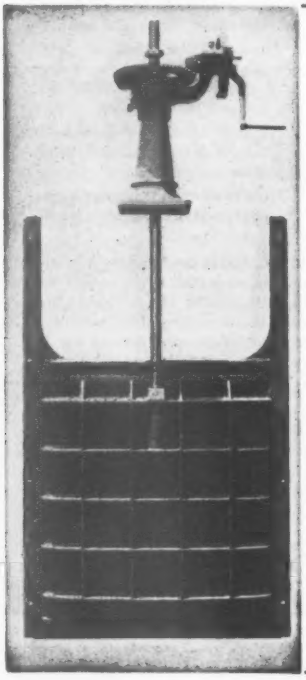
Lectures, panel discussions, and laboratory sessions comprised the bulk of the technical program, which was divided into seven "courses" comprising water chemistry, sewage chemistry, water distribution, sewer systems, waterworks, sewage works, and industrial wastes. Topics covered in the sewage and industrial wastes fields included the wide variety of interests of the group. Specific papers of general interest included:

"Civil Defense and Disaster Relief," by Gaines F. West, Director, Oklahoma State Civil Defense Board, Stillwater.

"Practical Application of Disaster Relief," by Dwight F. Metzler, Director and Chief Engineer, Kansas State Board of Health, Lawrence, Kans.

Of particular note were the industrial wastes section sessions on December 4 and 5. In addition to discussions of stream pollution by representatives of the state pollution control agencies of Arkansas, Colorado, Kansas, Louisiana, Missouri, New Mexico, Oklahoma, and Texas, the following papers were presented:

(*Continued on page 230a*)



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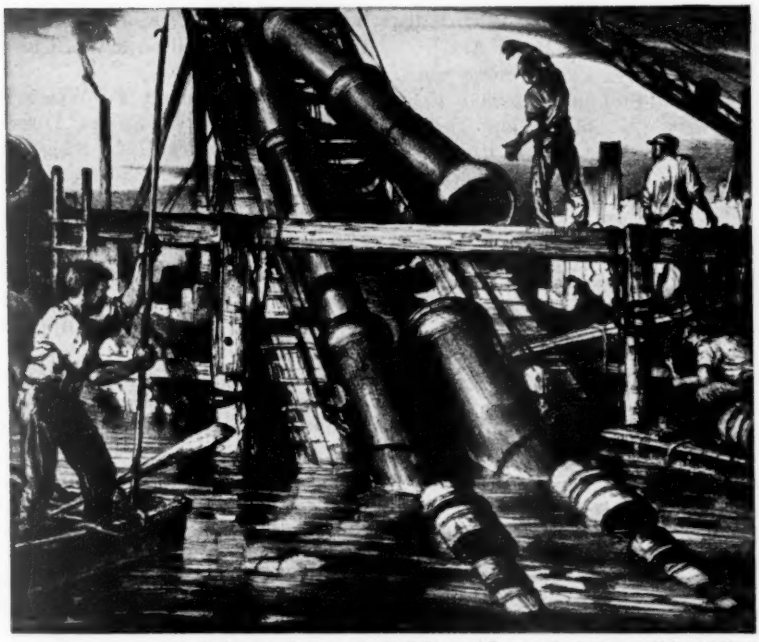

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"Industrial Wastes," by E. C. Warkentin, USPHS, Little Rock, Ark.

"Federal Stream Pollution Control," by H. J. Stafford, Attorney, Federal Security Administration, Dallas, Tex.

"Soil Conservation and Pollution Control," by A. D. Bull, State Soil Conservation Service, Oklahoma City.

"Wildlife and Stream Pollution," by Carl D. Shoemaker, Conservation Director, National Wildlife Federation, Washington, D. C.

"Agriculture and Stream Pollution," by M. G. Barclay, U. S. Bureau of Reclamation, Oklahoma City.

"Oil Field Wastes," by E. W. Hamburg, Oklahoma Planning and Resources Board, Oklahoma City.

"Oil Refinery Wastes," by J. W. Roach, Kerr-McGee Oil Industries, Inc., Oklahoma City.

"Waste Problem in Tulsa," By Glenver McConnell, Commercial Water Works and Sewage, Tulsa.

"Dairy Wastes," A. J. Steffen, Sanitary Engineer, Wilson & Co., Chicago, Ill.

"Waste Abatement *vs.* Waste Prevention," by V. M. Ehlers, Director, Bureau of Sanitary Enginering, State Department of Health, Austin, Tex.

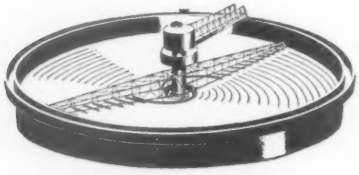
"Industrial Waste Research," by H. H. Black, Chief, Industrial Wastes Section; C. C. Ruchhoft, Chief, Physics and Chemistry Section; and C. M. Tarzwell, Chief, Biology Section, USPHS Environmental Health Center, Cincinnati, Ohio.

"Effect of Pollution in Other States on Waters Flowing into Oklahoma," by Fred G. Fellows, Consulting Engineer, Ponca City.

"Effect of Municipal and Industrial Wastes on Fish and Wildlife," by A. D. Aldrich, State Fish and Game Department, Oklahoma City.

"What the Farmers Are Doing About the Pollution Caused by Soil

(*Continued on page 232a*)



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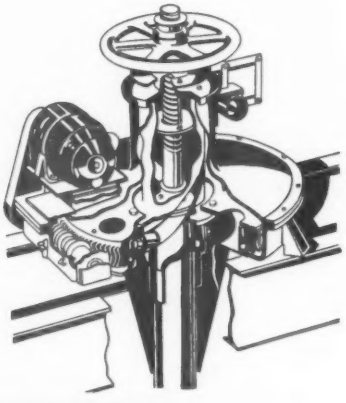

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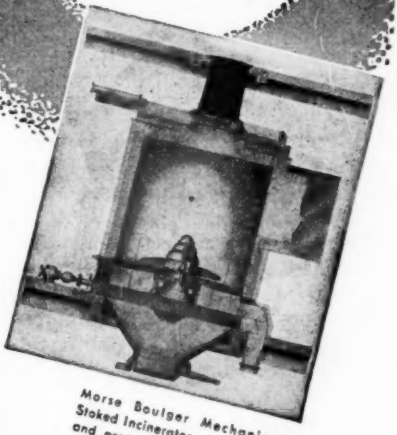

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GEORGIA WATER AND SEWAGE ASSOCIATION

The 1952 Annual Meeting of the Georgia Water and Sewage Association was held in connection with the 21st Annual Georgia Water and Sewage School at the Georgia Institute of Technology, Atlanta, Ga., September 24–26, 1952.

Papers of particular interest to wastes and pollution control personnel were as follows:

"Financing Water and Sewage Projects," by J. L. Morris, Vice-President, The Robinson-Humphrey Co., Inc., Atlanta.

"Lubrication of Water and Sewage Equipment," by B. H. Robson, Socony-Vacuum Oil Co., Jacksonville, Fla.

"Selection, Operation and Maintenance of Valves," by R. C. Kauffman, Wiedeman and Singleton, Engineers, Atlanta.

"Influence of Industrial Wastes on Sewage Treatment Systems," A. A. Kalinske, Director of Research and Development, Infilco Inc., Tucson, Ariz.

"Planning and Operating Sewage Works," by C. E. Drummond, Wiedeman and Singleton, Engineers, Atlanta.

"Operation of Sewer Cleaning Equipment," by Louis Cornell, Superintendent of Maintenance, City of Savannah, Ga.

Inspection trips were made to the Atkinson plant of the Georgia Power Company, and to Atlanta's R. M. Clayton sewage treatment plant.

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NORTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

The 24th Annual Convention of the North Dakota Water and Sewage Works Conference was held at the Gladstone Hotel, Jamestown, N. Dak., October 2–3, 1952. Registration for the meeting totaled 105.

The October 2 sessions were devoted to papers of interest to all members. This had been preceded on October 1 by an inspection trip to the new Jamestown Dam, on which construction had been recently started, and an evening smoker.

To insure free discussion on matters of more specific interest, the morning of October 3 was set aside for three concurrent sessions. The first group comprised those interested specifically in the problems of water treatment plants and water systems; the second, those concerned with sewage treatment and sewerage; and the third, those concerned with the general problems of water, sewage, public works, and other municipal utility problems of especial interest to the small town operator.

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Rust Preventive—SRP (Sure Rust Prevention) coating is described, with specifications and application data, in Technical Data Guide No. 10.—L. Sonneborn Sons, Inc., New York 11, N. Y.

Right Angle Gear Drive—New catalog contains full details and engineering data on right angle gear drives for 15- to 450-hp. installations.—Johnson Gear & Manufacturing Co., 8th and Parker St., Berkeley 10, Calif.

Turbidity Recorder—An "electric eye" turbidity, recorder is described in Bulletin 604, which also shows typical installations for various turbidity ranges.—ESS Instrument Co., Bergenfield, N. J.

Measurement Transmission Systems—New Catalog T-50 describes pneumatic, magnetic, electric, electronic, and electronic-follower transmission systems for use in measurement and control applications.—Fischer & Porter Co., 7250 Jacksonville Road, Hatboro, Pa.

pH Recorder—Units for automatic recording and control of pH are described in detail in Data Sheet No. 10.7-1.—Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.

Induction Motors—Totally enclosed induction motors for both standard and explosion-proof types in 1- to 2,000-hp. sizes are described with specifications and application data in Bulletin GEA-4400A.—General Electric Co., Schenectady, N. Y.

Dampers and Operators—Catalog 8502 describes various types and applications of dampers and damper operators.—Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.

Rotary Distributors—New 18-page Technical Supplement RD gives comprehensive design data and information on reaction- and positive-driven rotary distributors and dosing siphons—American Well Works, Aurora, Ill.

Spiragester—Details of the "Spiragester" are given in Bulletin 124, which also gives installation suggestions.—Lakeside Engineering Corp., 222 W. Adams, Chicago, Ill.

Flow Meters—Bulletin 300–J14 describes a new model in the Flo-Watch series of remote recording and controlling flow meters.—Builders-Providence, Inc., 345 Harris Ave., Providence, R. I.

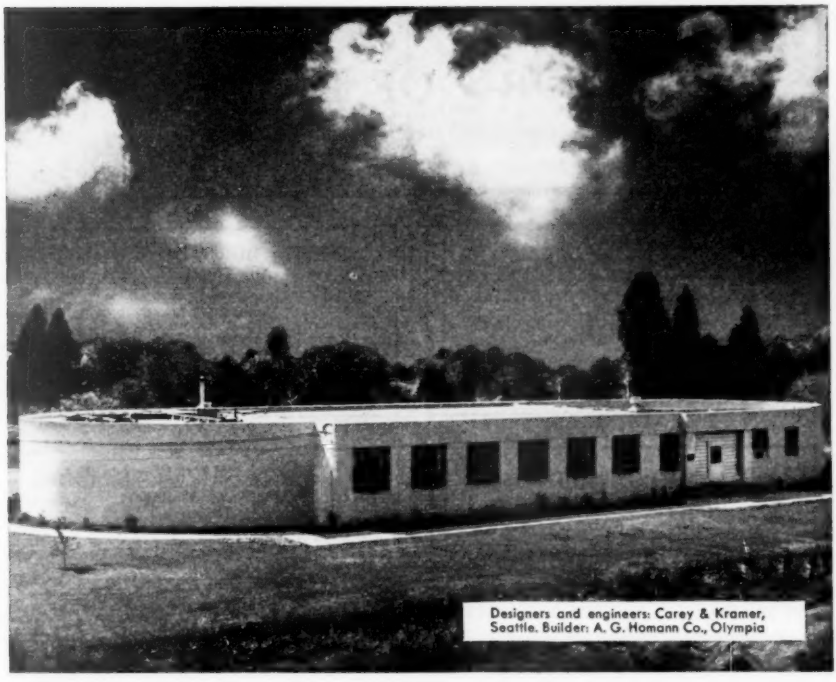
Sewage Pumps—Design and installation data for a complete line of small vertical sewage pumps is contained in Bulletin No. 7600.—The Deming Co., Salem, Ohio.

Bar Screen and Disintegrator—New 24-page Bulletin No. 6400 describes in detail two types of bar screens in connection with a screenings disintegrator.—The Dorr Company, Barry Place, Stamford, Conn.

Bucket Elevator—Bulletin 77–J7 contains complete details on a small, compact bucket elevator for loading feeder storage hoppers in limited areas.—Omega Machine Co., 345 Harris Ave., Providence, R. I.

Rotary Distributors—New 16-page Bulletin 5210 presents detailed descriptions of the various types of rotary distributors and the automatic dosing siphon.—Ralph B. Carter Co., Hackensack, N. J.

Corrosion Protection—New brochure presents data and practical suggestions on use of Tapecoat to combat corrosion of pipes, tanks, etc.—Tapecoat Co., 1523 Lyons St., Evanston, Ill.



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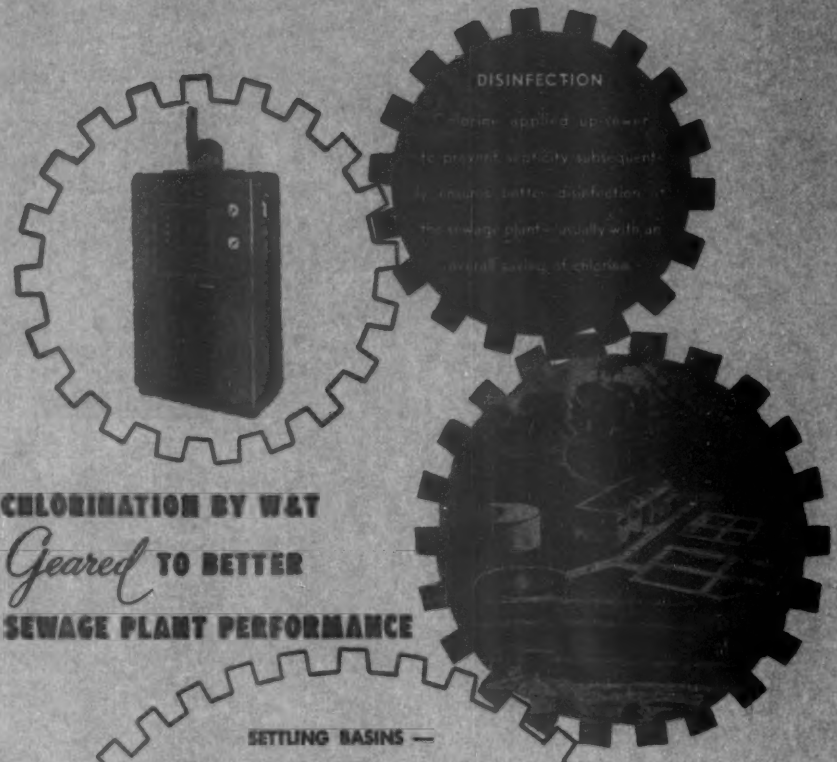

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